Mexican geothermal history and legends published in English, A compendium

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Regresar a Contenido

The fountains that spring forth in level
country they call *ameyalli*, which means "water that gushes."
Some of these springs are salty and have a bad
taste and bad odor …
To the springs that flow from their deep insides raising up the sand,
so that it seems that the sand itself is flowing,
they call *xalatl*, which means "sand water."
Fray Bernardino de Sahagún,
General History of the Things of New Spain

Through the centuries writers have published Mexican geothermal histories and legends, from the pre-Hispanic peoples of Mexico, to the Spaniards, to modern-day Mexican and non-Mexican authors. During the last 11 years, some authors have published such information in English. Today finding all the English texts can be confusing, as they appear in various publications of several organizations. This paper contains these texts—with some illustrations. To see all of the the photos and drawings, you'll need a copy of the original publication.

This paper also notes all the places each text was printed. As most were first printed by the Geothermal Resources Council in Davis, California, Ted Clutter, Executive Director of the GRC, has kindly given permission to reprint them here. The texts describe many areas of Mexico, including San Bartolo Agua Caliente in the State of Guanajuato, Paquimé in Northern Mexico, and Los Azufres Geothermal Field.

In the broadest sense the paper is incomplete—and not just because more information on Mexican geothermal history and legends must be in print. The truth is that most available data remain uncollected, still part of the lives of people living near the geothermal fields of Mexico and available for the asking to anyone interested in this unusual and fascinating topic.

Compendio de historias y leyendas geotérmicas de México publicadas en inglés

A través de los siglos se han publicado historias y leyendas geotérmicas de México, desde aquellas escritas por autores prehispánicos hasta las de autores mexicanos y extranjeros de nuestros días, pasando por las de los españoles. Durante los últimos once años algunos autores han publicado esta información en inglés. Actualmente, encontrar todos los textos en inglés puede ser difícil, porque han aparecido en diversas publicaciones de distintas organizaciones. Este trabajo incluye esos textos con algunas ilustraciones. Para ver las fotos y esquemas completos es preciso conseguir una copia de la publicación original.

El trabajo también refiere los sitios en los que cada texto fue publicado. Como la mayoría fue publicada por el *Geothermal Resources Council* en Davis, California, Ted Clutter, el Director Ejecutivo del GRC, ha otorgado su amable permiso para reproducirlos aquí. Los textos describen muchas áreas de México, incluyendo San Bartolo Agua Caliente en el Estado de Guanajuato, Paquimé en el norte de México, y el campo geotérmico de Los Azufres.

En un sentido lato este trabajo está incompleto, y no sólo porque seguramente hay más información sobre historias y leyendas geotérmicas en México en prensa. La verdad es que la mayor parte de los datos disponibles aún no se han recopilado y siguen siendo parte de las vidas de los pobladores de la periferia de los campos geotérmicos de México, al alcance de cualquiera interesado en este tema fascinante y poco común.

1. SAN BARTOLO AGUA CALIENTE, GTO.

The following text, with some illustrations not included here, is published in the *Transactions* of the Geothermal Resources Council, Vol. 27, 2003. In addition, the abstract in Spanish was published by CFE, along with Spanish-language versions of all abstracts for papers presented at the meeting of the Geothermal Resources Council in Morelia, Mexico, October 12-15, 2003.

The text is also in the *Geo-Heat Center Quarterly Bulletin*, Vol. 25, no. 2, July 2004. It is included on the website of the Geo-Heat Center.

Un Magnífico Spa, Manantiales Termales de San Bartolo Agua Caliente, México

A Beautiful Spa, Thermal Waters at San Bartolo Agua Caliente, Mexico

By Susan Fox Hodgson

***Keywords*:** Hot spring, spa, San Bartolo Agua Caliente, Mexico

Resumen

En San Bartolo Agua Caliente, una pequeña localidad rural en la Faja Volcánica Mexicana, funciona actualmente un *spa* en medio de las ruinas de un antiguo complejo mucho mayor que incluía originalmente un orfanato, un hospital, y un hostal para viandantes. Es uno de los primeros *spas* coloniales de México. El *spa* fue tan bien construido al final del siglo XVIII que en la actualidad permanece virtualmente sin cambios y emplea el mismo sistema de plomería de entrada y salida y las mismas piletas. El único cambio es la tubería que bordea los tanques externos de concentración, los cuales siguen en buen estado de funcionamiento. Los lugareños disfrutan sumergirse en aguas calientes que brotan de la misma fuente artesiana que desde siempre ha alimentado los baños.

Introduction

In San Bartolo Agua Caliente, a small rural town in the Mexican Volcanic Belt, a spa operates today amidst ruins of a much larger, ancient complex that originally included an orphanage, hospital, and a hostelry for travelers. This was one of the first colonial spas in Mexico.

The spa was so well engineered that it remains virtually unchanged today from the time it was built at the very end of the 1700s. It uses the same outside and inside plumbing and interior collection basins. The only change is the new pipeline that circumvents the original outside, hot-water collection tanks that remain in good working order and are interesting to look at. People still enjoy soaking in the spa's thermal waters flowing down from the same artesian spring that always has replenished the baths.

Fig. 1. Location of San Bartolo Agua Caliente, México

Story of the spa

A small, isolated town in the north-central part of the Mexican Volcanic Belt, San Bartolo Agua Caliente lies about halfway between the Cities of Celaya and Querétaro (Fig. 1). Described over 100 years ago as a jewel in the midst of the brown hills surrounding it, San Bartolo became famous for mineral waters and baths. Today in rural Mexico, it is a tiny, out-of-the-way place with a dirt road winding to its heart past the remains of a magnificent complex, announced by a sign at the entrance as the Antiguo Hospital de Baños Termales de San Bartolomé, or the *Ancient Hospital of Thermal Baths of Saint Bartholomew 1599-1802.*

The complex, dedicated to St. Bartholomew, patron saint of nervous and neurological diseases, was built next to ancient waters famous for hydrotherapy and cures.

Several structures once stood here—a church, a home for Catholic orphans and homeless, a hospital for the sick and traveling, and thermal baths for all (Fig. 2). Today most of the buildings are in ruins—except for the baths that remain open at this ancient, extraordinary spa.

For good reasons, the dates of the sketchy and mysterious story of the complex do not correspond exactly with the sign at the door reading 1599-1802, but they come close. In

Fig. 2. Sign outside the complex welcoming visitors to the spa and restaurant, today communal property owned and operated by an ejido. The spa entrance is the bricked archway on the right, the central dome covers the church ruins, and the bell tower is on the left.

fact, the 203-year period noted on the sign in photo 3 is critical to the history of the complex. This is what happened.

On July 4, 1602, Doña Beatriz de Tapia died and left money in her will for the project's construction. A lawsuit stalled the work until 1770—168 years later—and it was not until 31 years after this, in 1801, that the complex was finally finished. It is likely Doña Beatríz's project was blessed by the church a few years before she died, perhaps in 1599—the first date on the sign. It is also likely the complex was dedicated formally in 1802, a year after building ended and use had begun of one of the first colonial thermal spas in Mexico—the second date on the sign.

Fig. 3. Interior patio built in the Spanish style. The church dome and top of the bell tower appear in the background.

I don't know all the reasons for the ruins of today—earthquakes, war, neglect, or a combination—but this is what I learned of the spa's history. In 1844, 43 years after construction, the site of San Bartolomé was occupied by the Mexican General Antonio López de Santa Anna, who wanted to buy the property and who was in and out of the presidency of the country at least eight times in the politically turbulent years between 1832 and 1855.

The Departmental Assembly of the State of Guanajuato, where San Bartolomé is located, *"vainly protested the sale of the property to him,"* according to a history of Guanajuato written in 1860. Probably in 1846, the administration of General Mariano Paredes y Arrillaga annulled the sales contract, also in vain. General Santa Anna finalized the transaction in the year 1847. (From 1846-47, he was again President of Mexico.) Now, sadly predicted the author of the history *(Noticias, 1860), "This magnificent hospital will be ruined within a few years."*

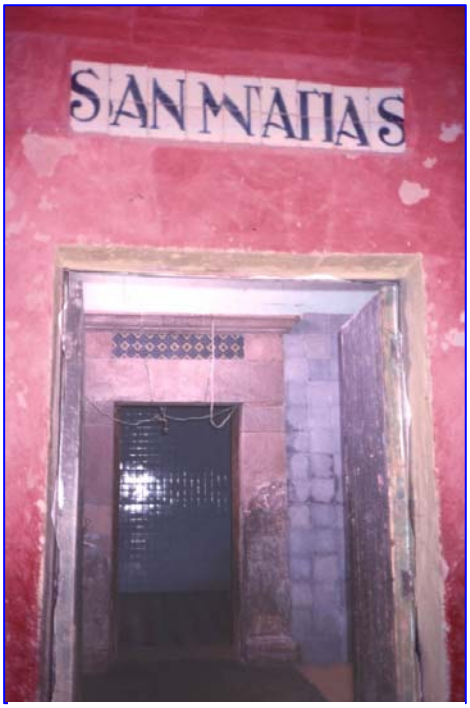

Fig. 4. Entrance to a two-room suite at the spa. Each suite has a different saint's name painted over the doorway.

But parts remain. Of all the buildings in the complex, the spa itself was most unaffected by destruction through the years, probably because it is a solidly built, single-story building. It is a large structure of carved stone blocks laid out along a large, open interior patio in the Spanish style (Fig. 3). Private, two-room suites for thermal bathers lead off from the breezeway around the patio and a different saint's name is painted brightly over the doorway for each (Fig. 4). Anyone entering a suite, sick or well, would be under the patronage of this saint, who would receive the visitor's prayers and act as a custodian.

Each suite is designed somewhat differently and some are larger than others. But all have two rooms, an anti-chamber for changing before entering the inner chamber with the thermal bath itself, everything built of solid stone—massive, shadowy, peaceful, and cool. All thermal-bath chambers have domed ceilings with cupolas whose tops are open, allowing light and air to enter and steam to escape. Propelled by gravity, the thermal waters pour through original plumbing into the large, hand-carved thermal basins cut in the floor.

The thermal waters, about 85° C, flow from an artesian spring on the side of a small hill above the spa to the south (Fig. 5). A small stone chapel stands by the spring, and neighbors living next to the thermal waters plant corn and beans in the warmed ground, sometimes cooking their meals in the steam.

Fig.5. Thermal waters from this spring flow into the aqueduct that goes down to the spa. The church dome in the spa complex is visible in the distance.

Hot waters from the spring pour down to the spa through an elegant, stone aqueduct (Fig. 6). Once the thermal waters reach the spa, they are still too hot to use and must cool before entering the bathing chambers, a process that occurred originally in two stages. As water arrived, it flowed first from the aqueduct into one of three stone troughs by slowly falling over a series of riffles, an air-cooling process that somewhat lowered the temperature. Next the thermal water was moved to a fourth stone trough where it was mixed with cold water until a temperature was reached that bathers could enjoy. Today a pipeline circumvents this cooling system, although the troughs and riffles still are there to see.

The author of the 1860 history writes that the baths of San Bartolomé have very hot mineral waters, and that the waters issue abundantly from many hot springs. He writes that once the water is cooled, it is healthy to drink and good for fattening cattle.

In conclusion

Such multiple uses of mineralized hot spring waters are typical worldwide. No one will ever know all the ways thermal waters have been used at San Bartolo Agua Caliente or all the ways they continue to be used there today.

Do you know more about San Bartolo Agua Caliente? Please e-mail me. I would be very interested to hear what you have to say.

Fig. 6. The original water-collection troughs built at the spa. At the far end are the riffles the thermal waters tumbled over on leaving the aqueduct, the first of two cooling processes. Next the waters were mixed with cold water from a fourth trough until a good bathing temperature was reached.

Acknowledgments

I would like to thank the Comisión Federal de Electricidad for its support and Ing. Arturo González Salazar, whose assistance with interviews and interest in what we saw made a big difference.

The essay is adapted from material published in 2003 in the *Transactions* of the Geothermal Resources Council and in 2004 in the *Bulletin* of the Oregon Institute of Technology.

Reference

Noticias para formar la historia y la estadística del Obispado de Michoacán (1860). Gobierno del Estado de Guanajuato, p. 145.

2. PAQUIME, CHIH.

The following study of the archaeological site of Paquimé (often called Casas Grandes) in northern Mexico was published, with illustrations, in the *Transactions* of the Geothermal Resources Council,

Vol. 25, August 26-29, 2001. The abstract was translated into Spanish and included by CFE in a volume of Spanish-language resumes of all papers presented at the GRC meeting.

The same text and some of the illustrations are published in the *Geo-Heat Center Quarterly Bulletin*, Vol. 23, No. 2, June 2002. It has been included on the website of the Geo-Heat Center.

New Information

The following information has become available since the original research was published.

Currently the large hot spring about two kilometers north and uphill from Paquimé—whose inviting waters once were channeled by the people of Paquimé into canals passing throughout their city—is on land owned by Don Antonio Varela Barba. Waters at the main hot spring have a temperature of 84 degrees F (29 degrees C), as measured in 2002 by CFE Ing. Germán R. Ramírez Silva. Today these waters are collected, filtered, and—along with other waters collected from other nearby hot springs—pumped downhill for domestic use by the people of Viejo Casas Grandes, a very small village at the eastern edge of Paquimé.

Geologists say individual hot-spring temperatures don't vary much through time. Thus we can assume the waters of the main hot spring are about the same temperature today as around 1200 years ago when they were used by the ancient city of Paquimé. The question is: Were the waters still hot by the time they reached Paquimé and flowed through the city buildings in narrow canals covered with flagstones?

The person who gave the answer is a modern resident of Viejo Casas Grandes named Luis. He said that today the water from the hot spring arrives at his house cold in the winter and hot in the summer. We have no reason to think the situation differed for the ancient peoples of Paquimé. In the summer, the water was hot when it passed through the canals cut through the town and in the winter it wasn't.

Were the flagstones covering the canals at Paquimé warmed by the hot waters in the summer? Did they radiate heat into the buildings? At the Roman ruins in Bath, England, the hot-spring waters measure 46 degrees C, a few degrees hotter than at Paquimé. They flow into the huge, main bath through a shallow, narrow limestone channel covered by thin slabs of rock, quite similar to the canals at Paquimé. I put my hand on the top of one slab and it was very warm from the heated water running below it, just as the flagstone covers would have been at Paquimé. Heat radiated from this stone, warming the air above it, just as it must have at Paquimé.

Therefore the new data and the more detailed archaeological study that follows make it reasonable to suggest that Paquimé is the site of the world's first city-wide district heating system.

Al fin calientes ("Warm at last")—
District Heating on the High Plains of Paquimé

By Susan F. Hodgson

Keywords: District heating, Paquimé, las Ruinas Casas Grandes, Mexico

Abstract

Paquimé, Mexico—also called las Ruinas Casas Grandes and about 280 km northwest of Chihuahua—is a Mexican national monument and an archaeological treasure. A city in ruins since 1340, in its 13th century prime Paquimé depended on unique, sophisticated hydrological systems. These may have included the oldest geothermal district heating system in the world, perhaps still unrecognized because few are familiar with geothermal systems.

Resumen

Paquimé, México, también llamado las Ruinas Casas Grandes y a unos 280 km al noroeste de Chihuahua, es un monumento nacional mexicano y un tesoro arqueológico. Ciudad en ruinas desde 1340, en su esplendor del siglo XIII el antiguo Paquimé dependía de sistemas hidrológicos sofisticados y únicos, que tal vez incluyeron el más antiguo sistema distrital de calefacción del mundo, el cual probablemente sigue siendo desconocido porque pocos están familiarizados con los sistemas geotérmicos.

Introduction

To ride across the vast high plains of northern Mexico is to recall the title of the Clint Eastwood movie, *High Plains Drifter*. For drifting is all that seems possible in lands like these—places too expansive for destinations, endless basins and ranges reaching beyond the horizon.

For a brief 56 years—from 1205 to 1261 A.D.—Paquimé, Mexico (also called las Ruinas Casas Grandes) was in its prime, a city about 280 km northwest of Chihuahua in a basin on these plains. Paquimé relied upon many innovative hydrological systems—perhaps including a geothermal district heating system begun around 1060 A.D. If this proves true, the Paquimian system is the oldest geothermal district heating system in the world.

How the city came to be as it was—and why its golden era was so brief—are integral parts of a complex hydrological story that includes geology and cultural history.

Geology

As late as Eocene time, northern Mexico was cut by the Laramide orogeny. Large fault blocks of Mesozoic and Paleozoic rock—including rugged volcanics—became mountain ranges stretching northwest-southeast, usually between 1,000 and 2,000 meters above sea level, their bases hidden in basins of Cenozoic sediment where hot springs sometimes bubbled up.

The parallel pattern of basins and ranges formed a great corridor, a north-south frontier passage where animals and humanity ebbed, flowed, and intermingled through millennia, including mankind who arrived about 10,000 B.C. in the shadow of Pleistocene megafauna.

Cultural History

Paquimé, Mexico, is near the center of what is called the Casas Grandes Archaeological Zone in northern Mexico and the southwestern United States. Vast and inexact, the zone equals about 170,521,470 sq. km (Fig. 7).

The zone was populated by Chichimecans, rugged individualists from all accounts. They included several mixtures of Mexican peoples, depending on the chronicler, so the exact composition is unsure. The Chichimecans lived in small hunting groups for hundreds of years longer than their southern neighbors, unable to risk agrarian communal living (without irrigation) in a climate such as theirs.

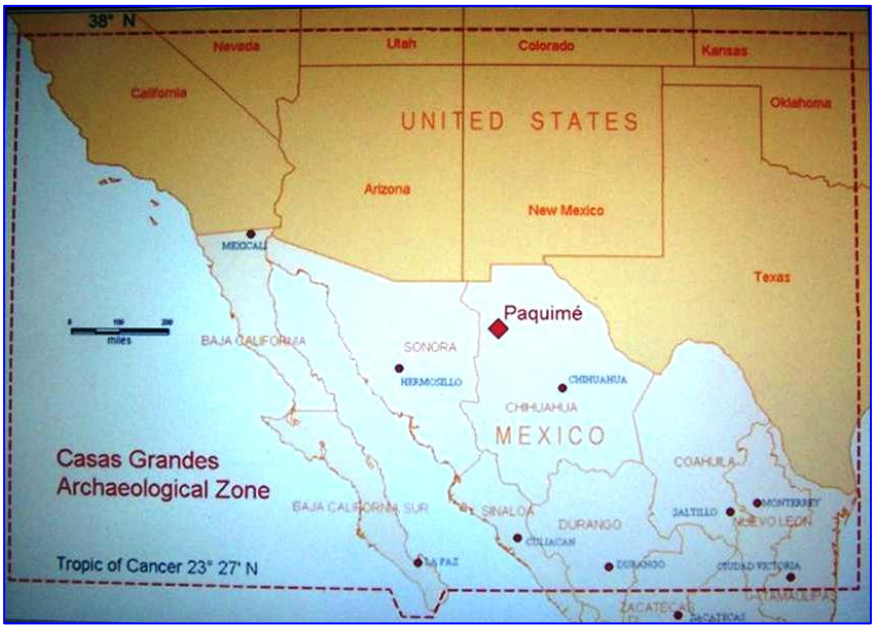

Fig. 7. Paquimé, Mexico, at the center of the Casas Grandes Archaeological Zone.

The great art and urban architectural traditions of Mesoamerica, including skills such as irrigation, evolved in the highly organized, agrarian cultures in southern Mexico, where between 1900 and 1500 B.C. people became full-time agriculturists.

Paquimé: The Beginning

Chichimecans began living together at the site we call Paquimé between 700 A.D. (±50 years) and 1060 A.D. This may have been inspired by contacts with southern merchants, for by now long trading caravans moved throughout southern Mexico and then northward, exchanging products and ideas. Highly civilized southern Mexico had reached its *Classic Period*. In general, this was a time of change in both southern and northern Mexico—destruction of civilizations and power shifts in the south and growth of communities in the north. Gradually life in Paquimé altered and architecture and artifacts became more complex. By the mid-11th century, the dominion of Paquimé had grown to include over 220,150 sq. km of land and several thousand satellite or culturally associated villages.

These socio-cultural interrelationships were created and nurtured by southern merchants based on their own direct economic ties to one or more older southern cities. The merchants, called *puchtecas*, were commoners—chosen as advisors and war captains to kings, merging military and trading activities in southern Mesoamerican society. A merchant in a frontier post was under the direct control of a home merchant with military, religious, and mercantile responsibilities. The *puchtecas* provided information about new areas, new customs, and trails and raw materials. They negotiated trade treaties and guided conquering armies.

Archaeologists assume *puchtecas* came to Paquimé from a relatively complex hydrological culture (or cultures) in Mesoamerica. The first sent were—naturally—in disguise to gather data about the

town. Turning Paquimé into a major trading center was a major undertaking, and *puchtecas* carefully calculated risks and benefits. They considered the amount of exploitable raw materials available; the hydrological potential—at least one major water source was needed to feed a hydrological system; the climate—a complete plant growth cycle was critical; the acreage of fertile soil accessible to irrigation; and geography in terms of transportation. Paquimé was near the center of all the Chichimecans, on the southern edge of a turquoise-producing area and in an important north-south corridor with enough people to support economic growth. The *puchtecas* negotiated "rights-of-passage" treaties with enemies on all sides of the city, safely linking Paquimé to both the raw materials needed to make goods and the markets to sell them.

Paquimé: Its Prime

Under the helm of the *puchtecas*, Paquimé was rebuilt from the ground up. It became a dazzling planned, model city that reached a pinnacle of prosperity from 1205 to 1261 A.D. Influenced by its merchant "professional rulers," the city "…changed from a conglomerate of single-storied, ranch style house-clusters to a massive, multistoried, high-rise apartment house covering some 36 hectares. The former were either razed, remodeled, or abandoned; the earlier city water system was revamped to accommodate the remodeling; and the city planners surrounded this new housing complex with a ring of ceremonial structures including effigy mounds, ball courts, a market place, stately open plazas, and other specialized edifices. Obviously, the Paquimian authorities had not only the power to relocate the inhabitants, but control of the required labor and building materials to carry out this change" (Di Peso, 1974b, p.313,314).

In 1584, Obregón described Paquimé in its prime, writing, "…this large city… contains buildings that seemed to have been constructed by the ancient Romans. It is marvelous to look upon… There are many houses of great size, strength, and height. They are of six and seven stories, with towers and walls like fortresses for protection and defense against the enemies who undoubtedly used to make war on its inhabitants. The houses contain large and magnificent patios paved with enormous and beautiful stones resembling jasper. There were knife-shaped stones which supported the wonderful and big pillars of heavy timbers brought from far away. The walls of the houses were whitewashed and painted in many colors and shades with pictures of the building" (Hammond and Rey, 1928, *in* Di Peso, 1974a). The name "Paquimé" may come from the Náhuatl language: pa ("big"), ki ("house"), mé ("s").

Thousands of hours were probably spent rebuilding the city, cutting and transporting timbers and gathering construction mud and other supplies. We believe this fascinating architectural rebirth occurred only at Paquimé, not in surrounding areas. However hundreds of mountain and valley satellite villages around Paquimé helped supply its needs, freeing Paquimians to create "…architectonics, ceramics, jewelry, and lithic [objects]" (Di Peso, 1974b, p. 333). City life now meant exciting daily markets, busy workshops for pottery and other trading goods, ball games, and ceremonial pomp.

Paquimé: The Fall

By the mid-13th century times had changed again, and in the city itself "…two and one-half generations sat idly by and watched the magnificent city of Paquimé fall into disrepair. Artisan-citizens continued to produce an abundance of marketable goods, but civil construction and public

maintenance all but ceased. The populace crudely altered public and ceremonial areas into living quarters… The walls of the city crumbled and, apparently unconcerned, people laid rude ramps over the rubble to reach still usable upper rooms" (Di Peso, 1974b, p.319).

"The city water and reservoir system was no longer maintained, but left choked by debris and used as a burial area. More hopeless were the cistern drains, which emptied the enclosed plazas of rainwater. These, too, were permitted to go out of commission. The remaining population stole the capstones of the drains and buried their dead in them" (Di Peso, 1974b, p.666).

Were the last years ones of economic depression when export markets were lost? Were there natural calamities like earthquakes? Were Paquimians characteristically casting off social oppressors, retrenching to better survive (Di Peso, 1974b, p.309)? No one knows.

Whatever the cause, the bitter end for Paquimé came around 1340 when unknown enemies attacked the city. Igniting the first-floor master beams, they destroyed Paquimé, collapsing it upon itself like a house of cards. Hundreds were killed inside the houses and in the public areas. Objects on altars were defiled and thrown into the walk-in well, part of the abandoned city water system. Breeding macaws and turkeys were left to die in their pens and boxes. Only scavenging animals cleaned the slaughter. Through the years, earthquakes, desertion, and ruin have left Paquimé an abandoned, one-storied maze of brown adobe walls.

Some suggest the end was part of a chaotic and widespread frontier revolt against sophisticated

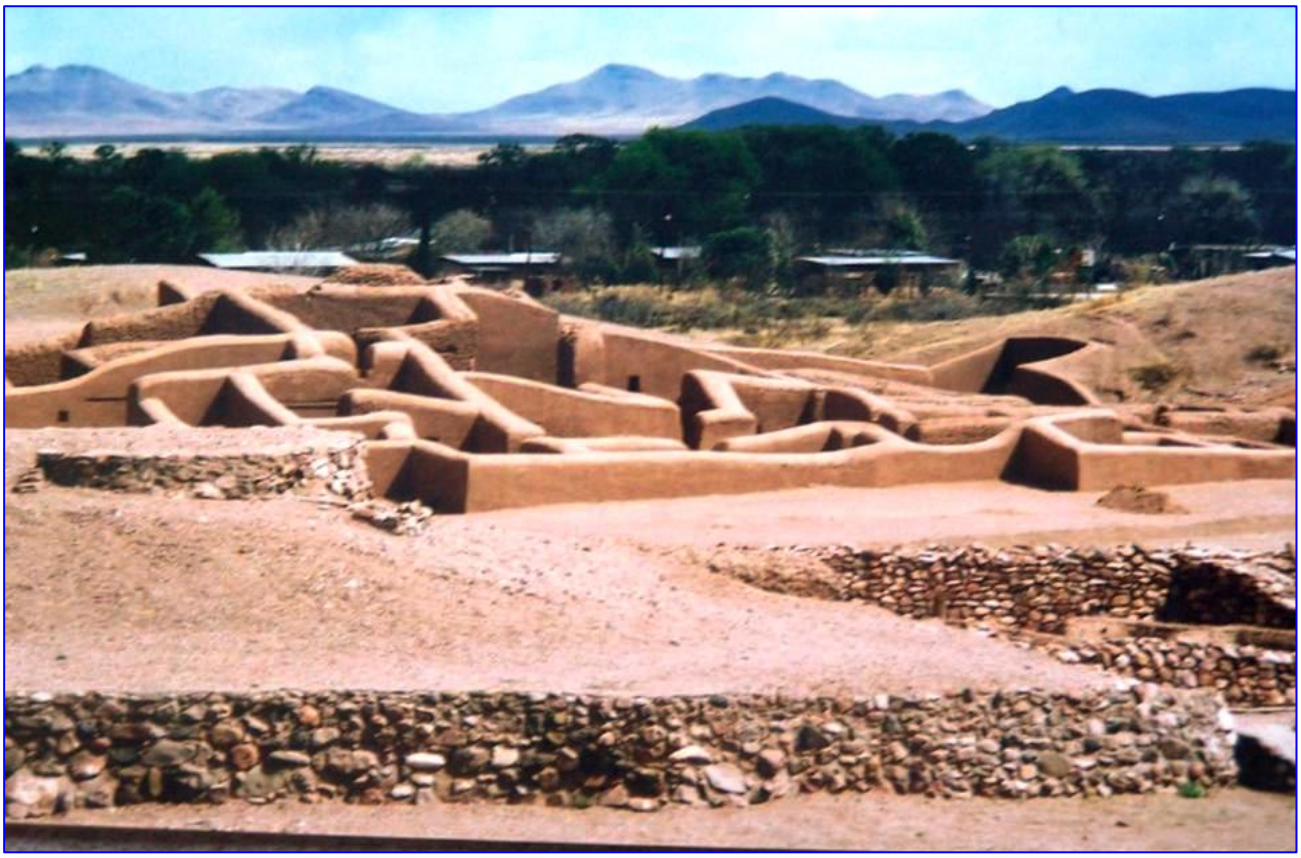

Fig. 8. Looking eastward across a portion of the dwellings at Paquimé. The walls were once several stories high. The small town of Viejo Casas Grandes is behind the trees.

Mesoamerican overlords and their practices, possibly triggered by a long drought (Di Peso, 1974b, p.321). In any event, the destruction coincided with the general collapse of established centers throughout the Gran Chichimeca.

The Water Systems of Paquimé

The city of Paquimé included two innovative water systems—both with multiple parts: one outside the city and one inside.

These systems supported a city built in reverse of most in southern Mesoamerica, which typically had ceremonial and public architecture at their centers and dwellings around the edges. The style chosen for Paquimé, with dwellings in the center and public and religious areas on the periphery, certainly maximized hydrological efficiency.

That the city was torn down deliberately and rebuilt just before its prime explains a fundamental puzzle about the amazing water systems at Paquimé. Clearly they were preplanned and in place before structures covering them were built. Yet the systems themselves are so sophisticated, they came late in the culture.

Outside the City: Surface Water- and Soil-Retention—Plus Irrigation

Paquimé, wrote Obregón in 1584, "…is located in some fertile and beautiful valleys surrounded by splendid and rich mountains and small mountain ridges. It is situated on the shores of the river… This is the most useful and beneficial of all the rivers we found in those provinces… It can readily and at little cost be utilized for irrigating the fertile shores" (Di Peso *et al.*, 1974, p.826).

On the slopes around Paquimé, *puchtecas* designed an elaborate, effective, surface water- and soil-retention system finishing as an irrigation system. The public project enhanced, protected, and irrigated the land, especially the 750 to 800 sq. km of deep, rich bottomlands in the lower Casas Grandes Valley, one of the finest valleys in the northern frontier" (Bartlett, 1854, *in* Di Peso, 1974b, p.337). An unforeseen benefit was increased agricultural land on the upper slopes because so much moisture and soil were retained there. Some 12,000 sq. km of a dendritic hydrological system were involved, an area of 80,000 hectares once subject to violent runoffs from high mountain thunderstorms.

The system controlled "…every raindrop which fell upon the mountainous southern and western borders [of the city]" (E.L. Hewett, 1908, *in* Di Peso *et al.*, 1974 p.825). To do this, stones were arranged in linear borders, terraces, check dams, and grid borders (Herold, 1965, *in* Di Peso *et al.*, 1974, p.826). Slope angles and erosive features determined placement. Some stones were piled in tiers and some aligned in single rows. The complex system, built as a unit, delivered clear water to irrigation canals that ran through fields in the rich lower valley—and to the river itself.

The interlocking system so safeguarded the rich valley-bottom farmlands from erosion and annual flooding that satellite farming villages were built there. Today such a choice is out of the question for people living around Paquimé, as the entire water- and soil-retention system is in disrepair. Angle by angle and rock by rock, it was custom-made to the terrain. Each part depended on the rest, and once maintenance ended, the system failed.

City Water and District Heating—the Oldest System in the World

The people who lived in Paquimé from about 700 A.D. (±50 years) to 1060 A.D. were first to collect domestic water from Ojo Vareleño, the nearby "hot" or "warm" spring. Archaeologists believe the first city water system channeling domestic water into Paquimian houses was built around 1060 A.D., and I believe the water warmed the rooms it flowed through, the start of the world's first geothermal district heating system.

From 1205-1261 A.D., as *puchtecas* rebuilt and ran the city in its prime, the original city water system was expanded and improved—along with the *de facto* geothermal district heating system.

The district heating theory depends on the waters of Ojo Vareleño in the low-lying volcanic foothills of the Cerro Prieto Mountains. The spring is 3.65 km northwest and up slope of the northern edge of Paquimé, as measured from the fork of the *acequia madre*, the main water channel of the city system, and the *acequia lateral 1*, the first lateral channel. The fork is visible on all photos and maps of the site. The spring has a flow rate of 11,400 liters per minute and is about 1501 m above mean sea level (Di Peso, 1974b, p.344).

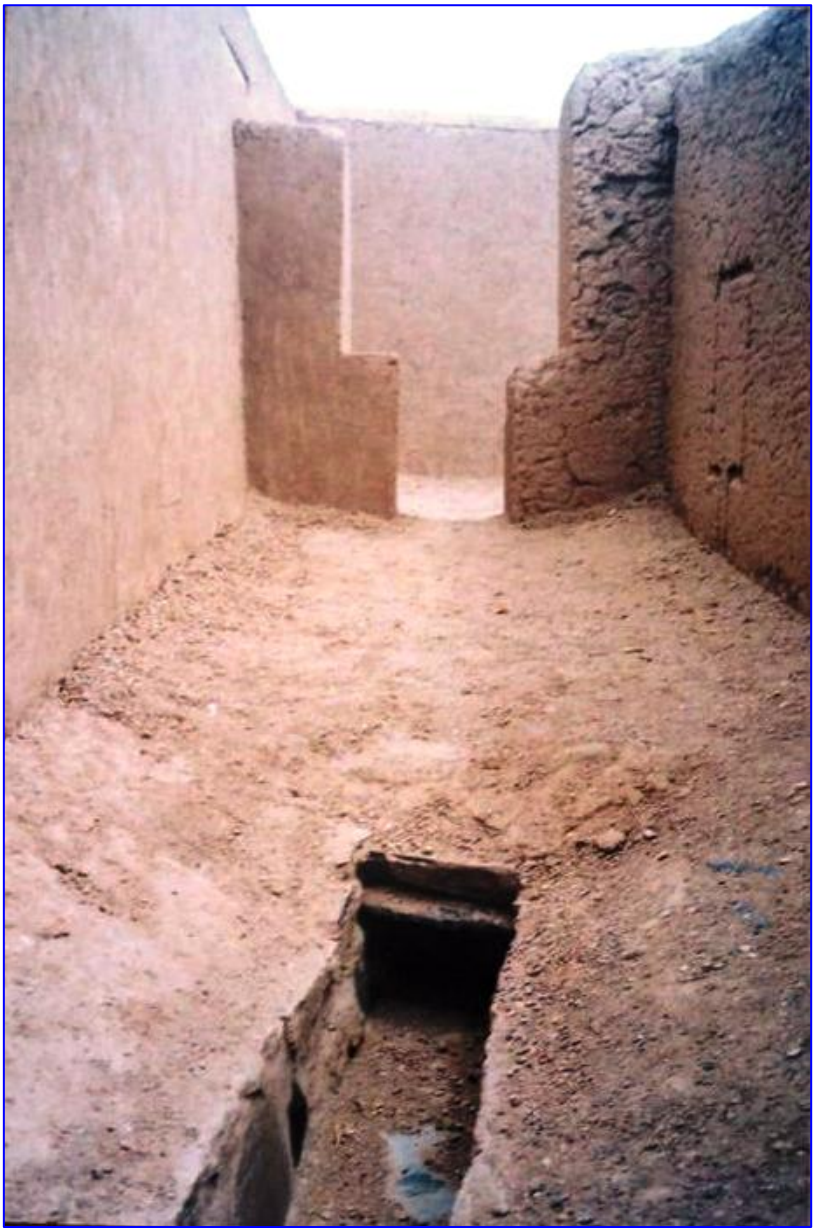

Fig. 9. A channel for thermal domestic water cut in the floor in the dwelling area of Paquimé. The door at the top of the photo has the typical shape used in the city. Note the smaller door shape incised in the wall, photo right.

In 1960, a cement dam at the spring ran "…north-south across the mouth of the Ojo de Vareleño arroyo below the spring's source, forcing the water to rise to the level of the *acequia madre* outlet, located 1.75 m. above and on the southern side of the Ojitos Arroyo. A similar contrivance, perhaps

made of earth and destroyed by the modern dam, must have been used originally to perform this hydraulic action" (Di Peso, 1974b, p.671).

How hot was the water? Spring water temperatures, sometimes described in the literature as "hot" and sometimes as "warm," have not been measured to my knowledge. The same spring water is used today in nearby Viejo Casas Grandes—about half way between Paquimé and the spring—and present spring temperatures could be colder or hotter than 941 years ago.

Stable isotopic analyses—or other geochemical tests run on spring water deposits on the rocks lining the *acequias* and channels at Paquimé—may tell us the water temperatures in the spring when the domestic water/district heating system was operating. Such analyses are made on sea shells to find the water temperatures of their natural habitats (Churchill, 2001).

At Paquimé, all the *acequias* were empty of water from about 1854 on in the literature I read. (A search of Spanish accounts from the end of the 1500s might prove otherwise for earlier times.) Much information about the *acequia madre* was noted by famed archaeologist Adolph Bandelier, who wrote in 1892, "The *acequia* is best preserved on the terrace northwest of the ruins. There its course is intercepted by gulches, and the section is therefore very plain. It seems that at a depth of about four feet below the present surface, a layer of calcareous concrete (caliche) formed the bottom of the shallow trough through which the water was conducted… It was carried on a steady and very gradual incline by means of artificial filling… The calcareous concrete forming the bed of the *acequia* may be artificial" (Di Peso *et al.*, 1974, p.831).

In 1890 Bandelier said portions of the *acequia madre* near the spring were 10 feet wide, and "...show traces of filling and of cutting. It is no longer the primitive method of slavishly following sinuosities of the ground in order to avoid obstacles. The ditch… runs almost straight… It rests on a bed of stones" (Di Peso, 1974b, p.344). Di Peso himself called the a*cequia madre* "stone- and adobe-lined" (1974b, p.345). The *acequia madre* was graded with a "delicate drop" of 0.4 cm per meter.

Water reaching the city flowed east from the *acequia madre* through three lateral *acequias* to various housing clusters, there passing into narrow channels incised in various ground-floor rooms (Di Peso, 1974b, p.344, and photos, p.348, 349). (Not all ground-floor rooms have channels and naturally none of the upper story rooms did.) In the Paquimé museum, an archaeologist showed an exhibit of a channel about 25-30 cm wide, made of flagstone-like rock on all four sides. All stones but those on top were cemented, possibly with caliche. If the water channels were like this and people inside rooms lifted loose stones at floor level to extract water for domestic use, I suggest they did so to adjust heat in these areas, as well.

This was possible because water flowing from the spring probably retained its heat for the distance to the dwellings. Hydrologists designing systems for Paquimé were too brilliant to have disregarded the heat, and a few heated rooms in the winter would be too welcomed to ignore. If this is true, Paquimé was the first city in the world to develop a geothermal district heating system.

New geologic and archaeological studies, combined with modern hydrological calculations, can help verify this. New measurements are needed of the flow rate; ancient and current spring temperatures; length of the *acequia madre* from the spring to the city; *acequia madre* width and gradation—a

grade is given, but I don't know how much of the *acequia madre* was measured to find it; grades of the *acequias laterales* and channels in the rooms; and annual air temperatures at Paquimé. Other data may be necessary, as well.

The city water system included three more features attesting to the hydrological genius of the city builders. One was a sewer system and one an extensive plaza-drainage system, built to empty water from the completely enclosed plazas after torrential cloudbursts. Drainage systems are not unknown in ancient Mesoamerican and southwestern sites, but they are not common (Di Peso *et al.*, 1974, p.853).

The third was a "walk-in well," a large multistoried room built under Plaza 3. The only such structure in the Americas, the room is well shored and vented for good air circulation. Stairways wind down to the water table at the bottom—a second urban water supply completely apart from the *acequias*. Halfway down is a detour to a secret room, perhaps built for religious reasons.

Fig. 10. Thermal domestic water flowed through this channel lined with flagstone-like rock in the dwelling area of Paquimé. The small pit has been identified as a tub for bathing. Photos by Susan Hodgson.

Conclusions

People with great hydrological imagination and skill developed the effective and innovative water systems at Paquimé. Outside the city, these included a surface water- and soil-retention system, and

inside the city a "walk-in well" unique to the Americas and what may be the world's first geothermal district heating system.

At Paquimé, channeling "hot" or "warm" spring water for domestic use through dwelling floors meant channeling heat. Housing residents could get water and change the air temperature by adjusting rocks over the channels. Thus the geothermal district heating system and the domestic water system may have worked together. New geological and archaeological studies may help prove this is so.

Most people are unaware of geothermal district heating systems. The possibility of finding one probably didn't occur to archaeologists studying Paquimé, and I didn't find the topic mentioned in the Di Peso volumes. Although the volumes discuss the *acequia madre* and *acequias laterales*—the large channels bringing water to the city from the "hot" or "warm" springs—these are not studied in the same detail as many other aspects of city life. There was no reason to do so if a geothermal district heating system was not at issue.

It would be interesting if geothermal and geological experts could visit Paquimé with an archaeologist and look at the city water system from a geothermal point of view.

Selected References

Note: Except for comments on geothermal district heating systems, information about Paquimé comes from the volumes by Di Peso, and Di Peso *et al.*

Churchill, Ronald (2001). Personal communication.

Di Peso, Charles C. (1974a) Casas Grandes, a fallen trading center of the Gran Chichimeca. Vol. 1. The Amerind Foundation, Inc., Dragoon, Arizona.

Di Peso, Charles C. (1974b) Casas Grandes, a fallen trading center of the Gran Chichimeca. Vol. 2. The Amerind Foundation, Inc., Dragoon, Arizona.

Di Peso, Charles C., J.B. Rinaldo and G.J. Fenner (1974). Casas Grandes, a fallen trading center of the Gran Chichimeca. Vol. 5. The Amerind Foundation, Inc., Dragoon, Arizona.

3. STORIES FROM A HEATED EARTH, OUR GEOTHERMAL HERITAGE

The book, edited by Raffaele Cataldi, Susan F. Hodgson, and John W. Lund, is published by the International Geothermal Association and the Geothermal Resources Council, Davis, California, where it may be purchased. The three chapters that follow are amply illustrated in the book. Only the text is reprinted here.

3. 1. Cosmogony and Uses of Geothermal Resources in Mesoamerica (Chapter 31)
By M.C. Suárez Arriaga, R. Cataldi, and S.F. Hodgson

"Mexico has as many volcanoes
as England does blackberries."
—10th International Geological Congress, Guadalajara, 1906

Abstract

Many Mesoamerican cultures developed in the Mexican Volcanic Belt, which runs east-west across Southern Mexico. For thousands of years, this was a place particularly rich in active geothermal manifestations, where intense contacts between mankind and geothermal forces deeply influenced the material lives of Mesoamericans and played an important role in basic decisions, such as selecting where to live. Vapor baths, cooking in steam at fumaroles or on naturally hot rocks, crop irrigation, and therapeutic applications were all ways that the Earth's natural heat was used in Mesoamerica.

Mythical and religious interpretations of geothermal phenomena occurred early on, reflecting a profound respect toward terrestrial heat. People's relationships with geothermal resources were beneficial and harmful, constructive and destructive. Volcanic explosions drove away populations, who then returned, drawn by the fertile soils, volcanoes, lakes, and natural heat. Mesoamerican peoples understood this duality, which deeply influenced their cosmic view.

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Introduction

Cosmogony is the science of the creation and evolution of the universe. This chapter treats some aspects, recently discovered, of the close relationship that existed between the development of Mesoamerican cosmogony and geothermal resources.

When opening any book on the history of science, one rarely finds a chapter dealing with science in pre-Hispanic America. However, Mesoamerican cultures created not only original art but also hydraulics, architecture, and mathematics. They developed autonomously the concept of zero, an advanced numerical system, and they made astronomical calculations with astonishing precision. Today, we know that scientific knowledge was a daily reality for Mesoamerican peoples. Less well known is their general concept of the world, how they questioned origin, being, and destiny. Their beliefs and knowledge originated from ideas about the cosmos. We want to demonstrate that their cosmogony arose, at least partially, from intense experiences with geothermal phenomena. To comprehend this vision, one must look at the natural environment, religion, and Mesoamerican mysticism.

For at least 4,000 years, human communities have resided in zones with geothermal manifestations throughout the Americas. Archaeological investigations show that stable settlements grew at the feet of all Mesoamerican volcanoes (Burgassi *et al.*, 1992). We can infer that since remote times, humans coexisted with volcanoes, with geothermal manifestations, and with other phenomena related to the Earth's heat.

Being predominantly volcanic, Mesoamerica was a region that included earthquakes, thermal waters, fumaroles, boiling muds, steaming grounds, and volcanic eruptions. Surface geothermal manifestations and the energy of the Earth were well known to ancient Americans. For millennia since prehistoric times, people had close contact with the energy of the Earth. Therefore, geothermal resources, in the widest sense of the word, deeply influenced the material, spiritual, and cosmic development of the Mesoamerican people.

A religious attitude toward volcanoes was widespread among pre-Columbian populations. Because of their magnificence and eruptive natures, volcanoes were considered sacred cult objects, often because so many volcanoes were nearby.

We have classified into two groups the available information about geothermal development in Mesoamerica, and a faithful approach to describing influences of geothermal phenomena incorporates both. Information from the first group is scarce, for it is based on direct facts described rigorously and is seriously limited by not going beyond documented evidence. One important original source was the Náhuatl texts compiled by the Spanish historian, Fray Bernardino de Sahagún, who began in 1534 to transcribe narratives of Náhuatl elders reciting what they had learned in Aztec schools.

The second, more abundant type of information is subjective and indirect, based on myths, legends, and oral testimonies that possess meanings simultaneously poetic, mystical, and religious. These references, which cannot be demonstrated, are based on intuitive faith in the authenticity of a story that liberates the imagination.

This chapter is a preliminary outline, not an exhaustive treatment of the subject. Our survey has a double objective: to explore the influence exercised by geothermal resources on the material and spiritual development of Mesoamerica and on the relationship between humans and territory, and to emphasize the historical antiquity of the influences by geothermal phenomena on cognitive processes.

The history of geothermal resources in the Americas still needs to be written; this brief document sketches that possibility for the first time. The theme is left open for new studies, in hopes that a better understanding may develop of the ancient history of Mesoamerica. “The culture of the old Mexicans, suddenly annihilated, was one which humanity could have been proud to create.... From time to time, in the infinite of the whole and amid the enormous indifference of the world, some men assembled in society and invented something that surpassed them, a civilization. They were the creators of cultures. And the Indians of Anáhuac, at the feet of their volcanoes, at the shores of their lakes, could be counted among those men” (Soustelle, 1955).

From Prehistory through the Post-classic Period

The origin of people in the Americas apparently does not introduce any epistemological problem, for researchers have not found human remains from predecessors of *homo sapiens* in the Americas, as they have in Africa, Asia, and Europe. Today, it is accepted that the proto-Americans came from Asia some 50,000 years ago, passing through the Bering Strait. The first immigrations could have been the “Amurians” or inhabitants of the Amur River shore in Siberia (Ruiz, 1987; Museo Nacional, 1996). A Mexican historian suggests these people could have come from southern zones

in Central Russia (Sodi, 1992). The Cahuilla, Sioux, Tolteca, and the Teotihuacano have facial features resembling the Amurians. That first passage could have occurred during the Wisconsinan glaciation that lasted from 70,000 to 30,000 years B.C., a date that agrees with the oldest ages of human fossils found in America (Carmona, 1993). The Mongoloid immigration perhaps included the forerunners of the Olmecas and the Maya and probably occurred around the year 12,500 B.C., at the end of the Woodfordiense interglacial period.

The first contacts of proto-American *homo sapiens* with geothermal phenomena probably happened in Southwestern Alaska, with nomads passing through the northern portion of the "Ring of Fire," an area between the North American and the Pacific plates. As new populations advanced southward into the Cascade Range, they found numerous active volcanoes and other geothermal manifestations. Eventually, their slow expansion reached the imposing manifestations of what is today Yellowstone National Park and The Geysers Geothermal Field in the Northwestern United States. Continuing southward into the enormous deserts of Arizona, New Mexico, and Texas, some ancestral nomads arrived at the great morphotectonic depression between the Imperial and the Mexicali Valleys at the Mexican border with the United States. By now, familiarity with geothermal resources should have been high.

Archaeological evidence indicates that North American Indians lived near hot springs for over 10,000 years and that all kinds of geothermal manifestations were sacred places for them, sites of refuge for rest and recuperation from warfare, havens for the elderly, and areas for cooking (Lund, 1995). The Indians believed that the Great Spirit lived at geothermal sites, a being providing heat and "the rejuvenating warmth of mother earth" (Lund, 1995). The breath of the Great Spirit was manifested through steam discharges and fumaroles.

In the remote and distant past, prehistoric peoples used volcanic rock, such as basalt, silica, and obsidian, to manufacture weapons and tools. Some 3,000 to 3,500 years ago, with the beginning of stable agricultural settlements, the first uses of natural heat arose. Tales and legends from pre-Hispanic sources tell of the use of thermal waters and mud to clean and cure the body, to temper arrows and lances for hunting and war (Suárez and Cataldi, 1993). Food was toasted or steamed by very hot stones. Ears of corn, potatoes, and meats were cooked this way.

The first archaic groups in North America spread slowly into the central and southern parts of Mexico, seeking improved soils and climates. Yarza de la Torre points out that volcanic activity in Mexico generally began about 62 to 63 million years ago in the Tertiary era, decreasing first in the Western Sierra Madre and lasting longer in the region between 18° and 22° latitude (Burgassi *et al.*, 1992).

This region, called the Mexican Volcanic Belt, forms an east-west band across Southern Mexico. It is characterized by an imposing series of 3,000 volcanic phenomena, 10 of which are active today. The sector is particularly rich in active geothermal manifestations such as thermal springs, fumaroles, gas exhalations, mud lakes, and volcanoes, and in hydrothermal deposits such as kaolin, sulfur, and iron oxide. This temperate region, with an altitude of 1500 to 3000 meters, became a choice area for settlements (Ruiz, 1987). Here, in the heart of Mesoamerica, a deep relationship grew between people and geothermal phenomena as civilizations evolved to high cultural levels through the centuries.

American civilizations developed apart from other influences, separated from Europe by the Atlantic Ocean and from Asia by the Pacific; they remained isolated for thousands of years from the discoveries and cultural mixtures of the Old World, and this separation made them unique.

Although many different cultures developed in Mesoamerica, one can speak of a Mesoamerican civilization because uniformity developed, a shared cultural inheritance. All Mesoamerican peoples had a common mental horizon: similar religious beliefs, a theocratic-military social structure, and a shared general concept of the cosmos. Mesoamerican peoples revered the same gods but gave them different names. Their cult objects represented things captured by the senses: volcano, sun, moon, wind, fire, water, corn, and then death—the end of the sensate realm and the start of the abstract. Mesoamericans knew peak periods and decadence, ascent and destruction, with no break in global continuity of a civilization built in a universe deeply religious, recurrent, circular, where all returns to its origin and everything begins again, uninterrupted by the outside world (Paz, 1992).

The history of Mesoamerica begins with the Prehistoric period, 10,000 B.C. to 2000 B.C.

• Formative or Preclassic, from 2000 B.C. to 100 B.C.

• Classic, from 100 B.C. to 900 A.D.

• Post-classic or Historic, from 900 A.D. to August 13, 1521. On this day Tenochtitlán surrendered to the Spanish invaders and the great destruction began (Sodi, 1992).

Mesoamerican peoples settled into permanent communities once they began cultivating corn. They were outstanding painters, sculptors, artisans of gold and copper, architects, poets, and creators of feathered embroideries and codices.

Religion that included sacrifice formed a basis for all Mesoamerican cultures, and rigor and asceticism were underlying concepts. The Aztecs called their supreme god Ometeótl, the Lord of the Duality, with feminine and masculine aspects. The double divinity was the creative principle, the origin of all beings and of all things, and the infernal counterpart was the Lord and Lady of Death. Such dualism is found at the base of Mesoamerican thought and is the root of Mesoamerican cosmology and ethics.

The relationship between humans and geothermal resources grew in America autonomously but more slowly than in other parts of the world (Cataldi *et al.*, 1992a and 1992b). Investigations and archaeological discoveries prove that 3,000 years ago, communities existed in many areas with geothermal manifestations and at the feet of all volcanoes in Mesoamerica.

Thus we can infer that from very remote times, people established a fundamental—and sometimes dramatic—relationship with volcanoes, geothermal surface manifestations, and with geothermal phenomena in general. Investigators of two Costa Rican volcanoes, Arenal and Miravalles, showed that life in the first settlements was regulated by volcanic eruptions. The eruptions drove off populations, which then returned to rebuild, drawn by the rich soil and other attractions in geothermal areas (Burgassi *et al.*, 1992).

Ceramics discovered at Miravalles indicate the presence of an agrarian population from the year 800 B.C. Sepulchral badges, shaped as very thin plaques, were extracted from laminar formations of volcanic rock and used by pre-Hispanic populations between 800 and 500 B.C. (Burgassi *et al.*, 1992). The geothermal zone of La Primavera, Mexico, is in a volcanic caldera with multiple domes, hot springs, and fumaroles. One of the domes, named Colli, contained obsidian arrowheads, and the hill is consecrated to the god of fire (G. Tibon *et al.*, 1967). A piece of obsidian was found that characterizes Iztlacoliuhqui, "the one twisted of obsidian," the god of punishment.

Various indirect references link Mesoamerican peoples to geothermal resources. Most consist of names of places, gods, and narratives about religious myths (Suárez and Cataldi, 1993; Hodgson, 1995; Hernández *et al.*, 1995). Some traditions and legends were transmitted orally and some were transcribed by Spanish friars. Many others, like most of the codices, were hopelessly lost. As an example, the indigenous informants of Sahagún, a Spanish historian, told him in about 1534 how travelers had arrived from remote regions, through the coasts of the Gulf of Mexico, coming to settle in a mythical place named Tamoanchán, where the Náhuatl culture first flourished:

"Here is the story that the old men used to tell:
'In a certain time that no one can any longer recount,
and which now nobody can remember....
Over the water, in their boats they came, in many groups,
And arrived at the edge of the water, on the north coast,
And where their boats were left, is called Panutla....
Off they went immediately following the water's edge,
Searching for the white and smoking mountains....'"

Why did these people seek to settle near volcanoes? The informants never said. The story suggests a deliberate decision, typical of the relationship between mankind and geothermal phenomena in America.

Cooking with pots in steam began with the development and diffusion of pottery, probably starting from the Late Formative period from 800 to 100 B.C. The pots were placed upon boiling water, on spouts of vapor, or on hot ground—a method still used in the geothermal zone of Ixtlán de los Hervores in Central Mexico.

Cooking food with steam is a traditional use of natural heat in Mexican geothermal areas. The Náhuatl term *Atotonilco*, which means "place of the boiling waters" (*atl*, "water"; *totonil*, "hot"; *co*, "place"), is a word used throughout Mexico. Twenty-five ancient villages possess this name referring to thermal waters, to their healing, divine, and magical properties. We can infer that, at least a millennium before the Spanish Conquest, many human settlements grew up here because geothermal manifestations were nearby. In fact, geothermal resources were used for cooking and cures throughout Central America (Suárez and Cataldi, 1993).

From time immemorial, American peoples took vapor baths by throwing cold water on hot rocks taken from the mouths of hydrothermal manifestations. They socialized, enjoying the vapors. Eventually, hot springs and thermal muds were used medicinally at some towns with the name Atotonilco and throughout the Mexican Volcanic Belt.

With time, some Mexican peoples began to use a structure called the *temazcal* for religious purposes (González, 1991). The *temazcal*, a dome constructed with volcanic stone and mortar, was warmed from the outside by showering cold water on piled rocks, heated by fire. The narrow corridor at the entrance was adorned with an image of Teteo Innan, the great goddess of the Earth and of childbirth, and the *temazcal* was used by pregnant women and babies.

Soon thermal baths were used widely in Mesoamerica. There were hundreds, all assigned with medicinal and divine properties with thermal waters between 20° C and 40° C.

Mexico had four famous gardens before the Conquest, and the most grand and beautiful was Oaxtepec. Located south of Mexico City, in the valley of Cuautla, it was founded by the Olmecas and preserved by all successive conquerors, finally becoming the summer residence of Aztec kings and the foremost botanical garden on the continent. One Aztec ruler, King Moctezuma I, sent messengers throughout the empire with orders to fill the garden with the most beautiful and rarest of plants, trees, and medicinal herbs. By the reign of King Moctezuma II, Oaxtepec had reached its greatest splendor and the emperor built temples, rooms, gardens, pools, and many *temazcal* baths for his noblemen and warriors.

The garden had abundant sulfurous thermal waters at temperatures of about 25° C that Moctezuma's warriors used for healing. The waters made a strong impression on the Spanish when they saw them (Bernal, 1532). The thermal waters were used, as well, to irrigate the garden. Oaxtepec was the first pre-Hispanic garden cultivated in Mesoamerica by a method known today as geothermal hydroponics.

Many Aztec structures were built with blocks of volcanic rock, often basalt. The upper classes of Aztec society made their homes with *tezontle*, a hard volcanic rock extracted from stony ground in what is today southern Mexico City. Mesoamerican minerals related to geothermal processes were used for weapons and tools and held mythical and religious meanings. For example cinnabar, the principal ore of mercury often associated with geothermal regions, was used to redden the bones of important personages, providing them with heat in the afterlife. Tezcatlipoca, one of the more important divinities, was characterized by a sculpture in obsidian and given the name of "smoky mirror." Obsidian was associated with death, magic, war, and fertility.

Mesoamerican Cosmogony and Calendar

For the Nahuas, the original supreme being was Cipáctli, a feminine monster that inhabited the sea. Two gods converted into serpents cut Cipáctli in two portions. From the first half they made the underground world and from the second, heaven. For the Maya, the cosmos was a structure formed by horizontal planes in which sacred powers lived who decided the destinies of all. For both cultures, the divine energies were land, corn, volcanoes, wind, rain, lightning, sun, and stars.

Two stable, visible bodies in the heavens are the sun and the Milky Way. For the Aztecs, Huitzilopochtli, the god of war born on Earth, represented the sun. His dismembered sister, the goddess Coyolxauhqui, characterized the Milky Way (Aguilera, 1979). This divine couple in the Aztec pantheon was considered the founder of the universe.

For the Nahuas, the Earth was a cylinder surrounded by water. The universe originated in the center of the Earth, in its navel where the god of terrestrial fire resided. From that navel, the four cardinal points were drawn. Above the Earth existed thirteen heavens and below were nine underground hells. Through the first heavens went the courses of the sun, moon, stars, and comets. The thirteenth heaven was the site of the divine duality, Ometéotl, the principle of generation and conservation for the cosmos, who controlled the universe with fire, earth, water, and air through the navel of the world.

Fig. 11. Hieroglyphic of fire. In the Aztec hieroglyphic for the third era, the "Rain of Fire Sun," the god of volcanic fire, elegantly arrayed and with lava pouring from his mouth, falls face downward between adjacent volcanic slopes outlined in escaping tongues of lava. He will envelop in flame a man and woman sitting beneath him in the protective circle of their home, still unaware of his descent. Turkeys fly around the couple, presaging the end of the third era when mankind is

Water was always related to the origin of Mesoamerican people, the basic element in one of the first epochs of their existence (León Portilla, 1992). At the horizon, the waters of the Earth joined the waters of heaven to envelop the world. That world was called *Cemanahuac*, “that which is surrounded by water.” The cosmic meaning of water was so important that in the Náhuatl language,

atl (“water”) came to represent the phoneme “a.” Tláloc, the god of rain, was worshiped throughout Mesoamerica, called “Chac” by the Maya, “Cocijo” by the Mixtecas, and “Tajín” by the Totonacas. In Náhuatl, “city” is translated as *atl in tepetl*, literally, “water-mountain” (León Portilla, 1992). Pilgrimages were made to volcanoes for several festivals marking dates on the solar calendar. The existence of lakes in craters of some old volcanoes reinforced the belief in the relationship volcano-water, which implicitly contains the idea that the mountains are large water reservoirs, kept by the gods of rain.

“All the high mounts, where the clouds join to make rain, are gods.
To each one of them an image is made....
Like the image of the volcano Popocatépetl (‘smoky mountain’)
Or of her whose name is Iztaccíhuatl (‘white woman’),
Or the image of the mount Poyauhtécatl (‘that which is from the region of the fog’)....”
—*From the* Florentine Codex

Ancient Mesoamericans believed that man and woman were necessary collaborators in the living universe. Both depended on nature in the same way that nature depended on them. Heat was the force that sustained life. Heat was equal to life; cold was equal to death.

In many chronicles, in the oral tradition, in indigenous manuscripts, and on reliefs of pre-Hispanic monuments, the idea is found that our era was preceded by four prior eras—named suns by the Aztecs. Each era ended with the destruction of the world by different, terrible cataclysm generated from the energy of the Earth. The bygone eras were those of *atl* (“water”), *ocelotl* (“jaguar”), *quiahuitl* (“rain”), and *ehecatl* (“wind”) (León Portilla, 1961). Each era had great mythical importance, and the meaning and the reason for the end of each follow.

Atl-Tonatiuh (“Water Sun”). The first people were made from ashes. In the first catastrophe, humanity was destroyed by water in the form of floods, and people were converted into fish.

Ocelotl-Tonatiuh (“Jaguar Sun”). In the second era, the sun stopped at noon, interrupting its path. Suddenly night appeared and heaven was oppressed. Now giants lived, who, in spite of great corpulence, were weak. When they fell by accident, they fell forever.

Quiahuitl-Tonatiuh (“Rain of Fire Sun”). In the third era, the rock boiled, burning the people in a rain of fire streaming down from volcanic eruptions (Tlequiahuitl) that destroyed the world. People in this era met a tragic end, changed into turkeys. The date 4-Quiahuitl, which records the end of this time, is placed under the protection of Tláloc, god of rain. He was also the god of fire, which fell from the sky as lightning rays and as volcanic eruptions (León Portilla, 1983).

Ehecatl-Tonatiuh (“Wind Sun”). During this era, everything was destroyed by the wind in the form of terrible hurricanes, snowfalls, and glaciers. Humans were converted into monkeys and scattered through the mountains. At the end of the fourth era, the gods met in Teotihuacán to recreate the world. With the sacrifice of one god, who flung himself into the fire of an active volcano, the Fifth Sun emerged.

Ollin-Tonatiuh (“Movement Sun”). This was the last of the eras, the era of the Fifth Sun in which we live and one that will be devastated by earthquakes. The divinity of the Fifth Sun is Xiuhtecutli, god of fire, who links the heat of the Earth with that of the heavens.

Our era is represented on the Aztec calendar by the date 4-Ollin, which means "movement and earthquake." The date 4-Quiahuitl, "end of the Rain Sun," is placed under the protection of Tláloc, god of rain. The third era ends in a rain of fire; Tláloc is not only the god of rain, but also the god of fire falling from the sky in the form of lightning and volcanic eruptions, equal to Tlequiahuitl, the rain of fire. Thus in four attempts, the world was born and destroyed from gigantic catastrophes, and this will happen once again.

In Mesoamerica the origin, existence, and development of the universe were the efforts of divine beings and came from divine energy in action. Therefore, religious understanding formed the basis of reality and Mesoamerican beliefs about geothermal manifestations were filled with fervent religious meaning with positive and negative dualities: both beneficent and harmful, constructive and destructive. The characteristics of three geothermal divinities illustrate this paradox.

Huehuetéotl was one of the principal gods, the oldest one, father of the other gods. He was the divinity who controlled fire, living in the "navel of the world," that is to say, at the center of the Earth. At the same time, he was the nearest to humans, *Tloque Nahuaque*, "sir of the neighboring vicinity," of the immediate present, who lived directly with people.

To the Aztecs, Huehuetéotl was fire itself, which came from volcanoes, the heat of terrestrial origin and the oldest principal generator of life who resided in the center of the Earth. The representation of Huehuetéotl as an old man suggests the antiquity of the mountains and the volcanoes. The age of this god underlines the importance given by the Mesoamericans to geothermal heat.

"Mother of the gods, father of the gods, the old god,
The one that is in the navel of fire,
The one who is confined in turquoise."
—From Náhuatl elders, León Portilla, 1956

Huehuetéotl was also the god of time. The museum of the great temple in Mexico City has basalt sculptures of the god, characterized in a similar manner by the Aztecs and the Teotihuacanos. The two snails on the head are located above streams of water, clearly related to Tláloc, god of rain and volcanic eruptions.

Tláloc was at the same time malevolent and beneficent: he enriched the soil with water but brought floods and disasters from hail, thunder, lightning, and volcanic eruptions. He represented a rain of water or a rain of fire. Chalchiuhtlicue was his feminine part, the goddess of running waters.

Tlazoltéotl was the Aztec goddess of carnal love and birth but also the goddess of vapor baths and confessions of illicit relationships. She was the goddess of refuse, lewdness, and spiritual impurities; she also was named *Cihuacóatl* ("woman-serpent"), a form of the goddess of the Earth presiding over part of the underworld, the world of the dead, the sower, and childbirth.

Mesoamericans were obsessed by the flow of time and the oldest known writings of the Zapoteca and Maya (600 to 400 B.C.) are closely related to the calendar (Joyce, 1979). The Mesoamerican calendar has existed since 700 B.C., structured as a complex measuring system based on the idea of time as flow. The Aztecs called time *Cáhuitl*, "that which is leaving us" (León Portilla, 1961). Time

began outside of human scope, at the beginning of the universe when vital activities of the gods created this world. The order in which the mythical actions occurred gave birth to the calendar, and every new being is named for the day it was created (López, 1990).

Cosmology is defined as a study of the philosophy of the universe as an ordered whole. Given the terrestrial nature of the oldest gods and the worldly origin of the sun and Earth, the symbols of the Aztec calendar representing days, months, years, and centuries reflect the influences of geothermal phenomena.

The calendar's cycles were of distinct dimensions and significance. The major cycle of 52 years was attached to the Pleides constellation, at whose completion was celebrated the festival of New Fire. It was related to terrestrial heat and probably represented periodical eruptions or earthquakes. This cycle was divided into four groups of 13 years each. The ritual activities corresponded to the agricultural cycles and, given that the calendar was based on the solar year, the principal function of the religious cult was to regulate social and economic life.

The premier ring of 20 days shows the importance ancient Mesoamericans placed on concepts related to geothermal processes: rain (water, fire, or eruptions), movement (earthquake), and serpents (related to the Earth and to things beneath it). Most surprising is the concept related to water (*atl*), essential in all forms and whose patron saint was the god of fire, Xiuhtecutli (González, 1991). The Aztecs used the words *atl tlachinolli* to say "water in fire," for which the geothermal relationship is evident.

The millennia of experience and wisdom accumulated by the Mesoamericans led them to a balanced existence between their societies and nature. Because of this, they revered water, corn, the volcano, the serpent, and the hummingbird. Thus Mesoamerican peoples studied and developed natural phenomena, including geothermal resources. Natural heat and its by-products, plus close observations of geothermal phenomena, influenced the shape of their cultural, ethical, religious, and social structures.

Selected References

Aguilera, C. (1979) Coyolxauhqui y la vía láctea. *CONACYT—Revista Ciencia y Desarrollo,* 24, 6-10.

Bernal, I. (1979) Una ciencia muy nueva, del Siglo XIX. Interview by M. García. *CONACTY—Revista Ciencia y Desarrollo,* 24, 22-26.

Broda, J. (1990) Calendarios y astronomía en Mesoamérica, su función social. *CIENCIAS—UNAM,* 18, 36-39.

Burgassi, P. D., R. Cataldi, J.L. Hernández Galán, M. Moggi, R. Rubinovich, and J. Saldaña (1992). Primera contribución al conocimiento historiográfico de la energía geotérmica en el área Mediterránea y en la América Latina. Contribution to *Simposio sobre la história de la geotermia,* Ciudad de Mexico. (This work has been published as a limited edition in the "grey literature"; it is available for consultation at selected places. Information on locations can be obtained from the first three authors of the publication).

Carmona M., M. Gómez, y S. Gómez (1993). *El origen del hombre en América.* García y Valadés, eds. 2nd ed. Museo Nacional de Antropología e Historia, Mexico, D.F.

Cataldi, R., P.D. Burgassi, and C. Suárez (1992a). La geotermia en el período Precolombino en las áreas Mediterránea y Mesoamericana. *Geotermia, Revista Mexicana de Geoenergía,* 8, no. 2, 145-175.

Cataldi, R., P.D. Burgassi, and C. Suárez (1992b). La geotermia en el período Precolombino en las áreas Mediterránea y Mesoamericana. *Geotermia, Revista Mexicana de Geoenergía,* 8, no. 3, 251-303.

De la Garza, Mercedes (1990). Cosmovisión de los Mayas antiguos. *CIENCIAS—UNAM,* 18, 33-35.

Díaz del Castillo, B. (1532) *Historia verdadera de la Conquista de la Nueva España.* Reprint 1961. Fernández Editores, Mexico, D.F.

González, Yólotl (1991). *Diccionario de mitología y religión de Mesoamérica.* Larousse. Mexico, D.F.

Hernández Galán, J.L., J. Guiza, and C. Suárez (1995). An overview of the historical aspects of geothermal energy in Mesoamerica. *Proceedings of the World Geothermal Congress,* Florence.

Hodgson, S.F. (1995) Heat over time, geothermal stories from Mexico. *Proceedings of the World Geothermal Congress,* Florence.

Joyce, M. (1979) Los orígenes de la escritura Meso-americana. *CONACYT—Revista Ciencia y Desarrollo,* 24, 35-52.

Krickeberg, W. (1956) *Altmexikanische Kulturen.* Springer Verlag, Berlin.

León Portilla, M. (1956) La filosofía Náhuatl, estudiada en sus fuentes. In *Monografía 10.* 7th ed. Instituto de Investigaciones Históricas, Serie Cultura Náhuatl, Universidad Nacional Autónoma de México, Mexico, D.F.

León Portilla, M. (1961) *Los antiguos Mexicanos a través de sus crónicas y cantares.* Colección popular no. 88. Fondo de Cultura Económica, Mexico, D.F.

León Portilla, M. (1983) Origen del nuevo sol en Teotihuacán, informantes de Sahagún, códice matritense del real palacio. In *Antología de Teotihuacán a los Aztecas. Fuentes e Interpretaciones Históricas, CIENCIAS—UNAM,* 57-8.

León Portilla, M. (1992) El agua: universo de significaciones y realidades en Mesoamérica. *CIENCIAS—UNAM,* 28, 7-14.

López, A.A. (1990) El tiempo en Mesoamérica. *CIENCIAS—UNAM,* 18, 28-34.

Lund, J.W. (1995) Historical impacts of geothermal resources on the people of North America. *Geo-Heat Center Quarterly Bulletin,* 16, no. 4, 7-14.

Museo Nacional de Antropología e Historia. 1996. *Personal communication.*

Paz, O. (1992) *El águila, el jaguar y la virgen.* Conaculta, Mexico, D.F.

Ruiz, F. (1987) *Los antiguos Michoacanos: visión de la prehistoria a la Conquista Hispana.* Morelia, Mich., Mexico.

Ruiz G., J.C. (1992) Los minerales en la mitología Mexica. *CIENCIAS—UNAM,* 28, 15-21.

Sahagún, B. de (1575). *Historia general de las cosas de Nueva España.* Reprint 1956, Porrúa, ed. Mexico.

Sodi, D.M. (1992) *Las grandes culturas de Mesoamérica.* Panorama, Mexico, D.F.

Soustelle, J. (1940). *La pensèe cosmologique des anciens Mexicains.* Hermann, Paris.

Soustelle, J. (1955) *La vie quotodienne des azteques a la veille de la Conquete Espagnole.* Lib. Hachette, Paris.

Suárez, M.C. y R. Cataldi (1993) La geotermia en Mesoamérica y regiones colindantes. *Geotermia, Revista Mexicana de Geoenergía,* 9, no. 1, 5-58.

Tibón, G. y J. Martínez Negrete (1967). *Mujeres y diosas de México, parviescultura prehispánica en barro.* Instituto Nacional de Antropología e Historia, México, D.F.

Vaillant, G.C. (1941). *Aztecs of Mexico, Origin, rise and fall of the Aztec nation.* Doubleday & Company, Inc., Garden City, New York.

3.2. An Overview of the Historical Aspects of Geothermal Influences in Mesoamerica (Chapter 32)

By J.L. Hernández Galán, J. Guiza Lámbarri, M.C. Suárez Arriaga

Abstract

Mesoamerica is a zone with ubiquitous geothermal manifestations that have always influenced the lives of its inhabitants through the increased fertility of volcanic soils and the damage inflicted on lands, settlements, and crops by volcanic eruptions and earthquakes. Some materials of igneous origin, like obsidian, were of utmost importance for the region's peoples. However, the influence of geothermal phenomena went beyond material implications to affect even religious matters.

The Europeans coming to this area reacted to the geothermal manifestations with awe, which was soon followed by attempts to explain their characteristics with scientific theories current at the time

or to exploit them. We summarize the interactions, both on utilitarian and nonmaterial planes, between mankind and geothermal phenomena in Mesoamerica.

Introduction

Industrial exploitation of geothermal resources did not start in Mesoamerica until the second half of the 20th century, so we will refer to geothermal energy in its broadest sense, mentioning the utilization its inhabitants made of the Earth's heat or igneous materials, and also the way in which phenomena, such as earthquakes or volcanic eruptions, influenced the lives of those peoples, their societies, and their beliefs.

To establish the early history of geothermal influences in Mexico, Central America, and the Antilles is a very difficult task for various reasons, mainly because our sources are fragmentary and often distorted. Besides, it was not until the studies of Knorosov and Proskouriakoff that Maya inscriptions were deciphered properly. Before that, we had only second-hand transcriptions made by early missionaries who considered the beliefs of the aboriginal populations to be the work of demons. On the other hand, although the native inhabitants of Mesoamerica left proof of their perception of geothermal phenomena in their place names and in their theogony, they were not much interested in utilitarian aspects, so they left very few records of the world that surrounded them.

The Peopling of Mesoamerica

In 1589, the Spanish Jesuit José de Acosta advanced the idea that American Indians had first come from Asia by land and, perhaps, by a short sea voyage. This is still the opinion commonly held, with the majority of experts dating the first human occupation to about 11,000 years ago, and some of them fixing it as far back as 25,000 years ago.

In any event, America was first colonized by modern humans that had already acquired many skills and presumably had developed systems of beliefs. Evidence from archaeological findings, anthropological measurements, analyses of mitochondrial DNA, and studies of comparative linguistics all agree that Mesoamerica was originally settled by the *Amerind* peoples on their migrations from Asia. After an archaic epoch in which the land was settled for the first time, the interval of human occupation is divided into three periods. The earliest one, termed *Preclassic* (or *Formative*), was from about 4,000 to 1,800 years ago. The next period, the *Classic*, extends to about 1,100 years ago, and the *Postclassic* period ends with the Spanish Conquest in the 16th century.

The Region

Mesoamerica is a land of very intense tectonic activity, so its first colonizers would have become acquainted with seismic, volcanic, and geothermal manifestations very soon. Chronologically, their first contact with these phenomena should have occurred in the Imperial and the Mexicali Valleys, where they could not have overlooked the conspicuous hot springs, mud volcanoes, steam jets, and mineral efflorescence. Similar manifestations also should have been evident to those arriving at the Neovolcanic Belt further south, with its 3,000 volcanic cones, abundant hydrothermal deposits, and numerous hot springs (Suárez Arriaga and Cataldi, 1993).

In Central America, the situation is comparable: Guatemala, with peaks such as Santa María and Fuego and lakes formed in volcanic craters, like Atitlán and Amatitlán; Honduras, with Conchagua and others; El Salvador, with its central valley so affected by seismic activity that it is known as the *Valley of the Hammock*; Nicaragua, with Momotombo, Negro, and Santiago volcanoes; and Costa Rica, with the steaming grounds of Rincón de la Vieja and the peaks of Poas and Irazú, to name only a few from a long catalogue of tectonic and thermal manifestations. We know that they were of importance to the early settlers in the region, because close to the manifestations it is common to find offerings dating from the very early Preclassic period.

Influence of Geothermal Activity on Mesoamerican Peoples

Weathered volcanic soils, because of their enhanced fertility and ability to retain moisture, allow the growth of a dense and varied flora that supports abundant animal life. These elements make an area attractive to people, from nomadic hunter-gatherers to intensive farmers (Grayson and Sheets, 1979). The end result is that people concentrate around places with geothermal activity and, in so doing, expose themselves to potentially disastrous volcanic eruptions and earthquakes. The impacts of these events on the environment and on the societies established around them vary, depending on the magnitude of the event and its precise nature and characteristics. The impacts also depend on components related to the social organization of the settlers, their hazard perception, land use, and so on.

The pre-Columbian Mesoamerican societies were no exception. The influence of geothermal activity is exemplified by the volcanic eruptions of Xitle, Arenal, and Ilopango. The latter's eruption five centuries ago may have ended southeastern Maya civilization and allowed people from Northern Guatemala to seize lucrative trade routes. Some Maya lowland sites, like Barton Ramie in Belize, apparently received refugees from that event, whose sudden arrival may have produced not only agricultural adaptations, but greater political centralization and class differentiation as well (Sheets, 1979).

The Maya living 1,400 years ago in Cerén, in what is now El Salvador, also experienced the impacts of geothermal activity. A rapid series of explosive eruptions took place within two kilometers of their village when rising magma encountered ground water. Buildings were demolished and then buried by ash and pumice, preserving details of domestic Maya life: dirty dishes, pots full of food, and footprints in ash—all suggesting people fled the town (Fink, 1993). These cases agree with the studies made in Costa Rica by Sheets (1984) at Arenal, and Hurtado de Mendoza and Alvarado (1988) at Miravalles regarding the possible influences of volcanic eruptions on the socioeconomic, agricultural, and development of pre-Columbian local artisans. Their research has shown how human populations are driven away during and immediately after major volcanic episodes and then return, reattracted to the area.

Besides anthropological evidence, we have direct indications of how pre-Columbian Mesoamerican inhabitants were aware of geothermal phenomena. For example, many volcanoes in the area still bear autochthonous names, such as Iztaccíhuatl (*iztac*, "white"; *huatl*, "woman"), Popocatépetl (*popoca*, "steaming"; *tepetl*, "hill"), Citlatépetl (*citlali*, "star"; *tepetl*, "hill"); and some of the extant codices, like the *Nutall*, the *Tellerianus Remensis*, and the *Cuauhtinchán*, bear these representations in hieroglyphics. Many towns have Indian names referring to some geothermal characteristic of the

place: for example, Atotonilco (*a[tl]*, "water"; *totoni[li]*, "hot"; *co*, "place") signifies "place in the hot water" in Náhuatl. In Mexico, there are about 25 villages with that name. Also, there is a town named Puruándiro and a zone called Pathé; both names mean "place in the hot water" in the P'urhépecha and Otomí languages, respectively.

Codices hold expressive hieroglyphics for place names and for Mexican volcanoes. For Atotonilco ("place in the hot water") a drawing is used of a pot placed over fire. The volcano Popocatépetl is a simple bell-shaped curve with lava erupting from the top. In one drawing, the lava, shooting straight into the air, resembles leaves colored in and fastened asymmetrically to a corn-like stalk. A second drawing is more free-flowing. The erupting lava "leaves" are outlined—not colored in, unaffixed to a stem, and depicted as tear-like curves shot out against the sky. Eruptions of Popocatépetl were caused by the "departed spirits of wicked rulers whose fiery agonies, in their prison house, caused the fearful bellowings and convulsions in times of eruption," according to a legend recounted by William Prescott.

Two hieroglyphics for Citlatépetl, which means "star hill," depict a plan view of the volcano. On the first, the caldera with erupting lava is shaped as an eight-pointed star, colored in, and engulfed by a decorative circle representing the slopes of the volcano. The second hieroglyphic of the volcano has two parts. The plan view just described is drawn at the top of a vertical line seemingly suspended in air and swaying slightly. At its base, the line enters a small rectangular shape with tiny asymmetrical blocks at the surface depicting an earthquake. The hieroglyphic reads, "Citlatépetl was smoking when the Earth trembled."

Influence of Geothermal Activity on Mesoamerican Religion

The overpowering magnificence of geothermal phenomena and their connections with areas of bountiful resources, or else with death and devastation, made the ancient inhabitants of Mesoamerica quite naturally associate these manifestations with powerful gods who had to be propitiated. Consequently, archaeological caches frequently are found near places of geothermal activity. For example, Stone (1941b) describes a place called *Peroles Calientes* in the Black River Valley on the northern coast of Honduras, which "must have been a very important one to the natives, for the quantity of pottery to be found there is immense."

Food seems to have been the principal article offered to the hot water gods, because pot upon pot was placed upright, some within others, with the best pieces directly positioned under a hot waterfall. On the southern flank of Miravalles volcano in Costa Rica, offertory remains were discovered close to a lava outcrop that the ancient inhabitants revered. An additional example is that of the cache found under a stratum of volcanic sand on the slopes of Irazú volcano, also in Costa Rica. It amounted to more than 400 objects, including male and female figures, offering tables, and heads made from volcanic rock, plus some 100 wooden articles preserved from weather and insects by the layer of volcanic sand (Stone, 1941a).

These examples do not show whether these people believed there was a god residing at the place with the geothermal manifestations, or if they worshiped the phenomena themselves. Then again they may have perceived the geothermal manifestations as attributes of a god or representing the forces and elements the god controlled. This is what we have with Huehuetéotl, the oldest of the gods, who controlled fire from his dwellings at the "world's navel" that is, the Earth's center, or

with Xiuhtecúhtli, who united the fires of Earth and Sun. Tláloc was the rain god, but he could bring volcanic eruptions also, so he could produce rains of water or fire. Tezcatlipoca, whose name means "Smoking Mirror (Obsidian Mirror)," was the omnipotent deity of fate, both beneficial and destructive. Tlazotéolt Ixcuina was the goddess of carnal love and natality, who ruled over steam baths, and Itzpapálotl, whose name means "Obsidian Butterfly," was the goddess associated with Earth and fertility. These deities were not perceived by pre-Columbian peoples as clear-cut individuals, but as complexes of closely related gods or goddesses and attributes.

Raw Materials of Volcanic Origin

Many of the artifacts manufactured by the early Mesoamericans were made from volcanic materials: silica, flint, basalt, and very especially, from obsidian. Obsidian, a volcanic glass that fractures in flakes with sharp edges, was particularly good for making knives, spear or arrow points, scrapers, needles, and similar utensils. It is interesting to note that the Náhuatl name for obsidian is *itztli*, which means knife. Obsidian blades have been found at practically all Mesoamerican sites. When

Fig. 12. Many artifacts manufactured by the early Mesoamericans were made from volcanic materials, such as basalt. Two such items are still indispensible in a Mexican kitchen--the molcajete and tejolote, or "mortar and pestle." For at least 3,500 years, cooks have used them for grinding spices and mixing sauces

obsidian was not available locally, it was traded, as the following examples show. In El Salvador at Chalchuapa, the remains were discovered of a large shop for manufacturing knives. However, the obsidian flakes found there are from Ixtepeque volcano in Guatemala, some 50 kilometers away. Also, the obsidian knives found in Honduras at Copán were imported because no natural deposits of obsidian are known in that area.

Volcanic rock was used widely, as is exemplified by the cache already mentioned found on the slopes of the volcano Irazú, the tombs with lids made out of laminar volcanic formations *(lajas)*, and the sepulchral stelae carved on columnar basalt on the flanks of Miravalles volcano in Costa Rica (Ryder, 1983).

Indirect References

Spanish missionaries and chroniclers have left transcriptions of Indian legends and traditions that they collected, and in many of these one can find references to geothermal phenomena. For example, a myth recounting the migration of peoples searching for Tamoanchán says they "were looking for mountains: some white mountains and some smoking mountains." Would it be too farfetched to believe that these people were consciously trying to find for themselves a country fertilized by volcanic deposits and well irrigated by water from melted snow? In another example, a number of writers from the beginning of the Spanish colonization, like Fray Bernardino de Sahagún (1534) and Diego Muñoz Camargo (1540), tell in very similar words of signs that forewarned King Moctezuma II of the coming of the Spaniards. One of the omens, the *Fifth Prodigy*, seems to correspond to a phreatic explosion in the lake on the outskirts of the Aztec capital Tenochtitlán, now Mexico City (Burgassi et al., 1992).

The Aztecs believed that our world had passed through different epochs, called "Suns," and that each previous epoch ended with a cataclysm. They knew the last epoch as the *Fifth Sun*, which presumably is the one in which we are now living, and they said that "in it, there will be earthquakes." A prior epoch, the *Third Sun*, was the "Sun of the Fire Rain. And it happened that during it, there rained fire. And those who were living at the time burned out. And at the time, it rained sand also. And they say that in that Sun, it rained the pebbles that we now see, that the *tezontle* stone boiled and that the boulders reddened." It is hard not to conclude that we have here the description of a devastating volcanic event, one narrated by a frightened survivor and later transmitted orally for generations.

The Post-Columbian Era

The Mediterranean basin has been tectonically active since the most remote times, so the first Europeans to arrive in Mesoamerica were already acquainted with geothermal manifestations, either first-hand or by reference. Most of them probably had never been exposed to phenomena of the magnitude and frequency of those they witnessed in the New World. Their reaction was awe, as can be seen in the books of Juan de Cárdenas (1591), Bernal Díaz del Castillo (1568), Francisco López de Gómara (1552), and Suárez de Peralta (1589). An interesting narration is the one by Pedro Castañeda Nájera (1560) relating the discovery by the Melchor Díaz expedition of geothermal manifestations adjacent to a lagoon now named la laguna Vulcano. The area is near geothermal power plants now at Cerro Prieto Geothermal Field, the largest geothermal installation in Mesoamerica. According to the chronicler, "as they were walking, they arrived into dunes of boiling ash, so that nobody could advance through them... the land trembled."

Sometimes, the Spanish writers tried to provide an explanation of an event's origin, one in many cases of real scientific value, as happened with the description of the geothermal gradient offered, probably for the first time in history, by Gonzalo Fernández de Oviedo (1526). In other instances, they did not content themselves with theorizing about geothermal phenomena, but sought to gain

first-hand knowledge. A few examples were the attempts to sample the lava of the Masaya volcano by Fray Blas de Iñesta in 1551, or the different ascents of Popocatépetl while in eruption, the first one by soldiers of Diego de Ordaz, then the unsuccessful one by Antonio de Betanzos, and the one by Fray Bernardino de Sahagún, who, accompanied by four or five Spaniards, ascended to its very mouth "…and there were very big flames, and it boiled as a cauldron, and this bad thing expelled a large amount of sulfur stone... and, from very far away, one sees the smoke leaving, as in a furnace, except that the amount was huge."

The influence of geothermal events on the lives of Mesoamerica's inhabitants continued after the Conquest. On repeated occasions, earthquakes and related catastrophes demolished colonial cities. That was the case with Antigua, or Santiago as it was originally known, the capital of Guatemala that was destroyed by earthquakes in 1773; the present-day Guatemala City was inaugurated capital of the country in 1776. Cartago, the former capital of Costa Rica, was so ruined by an earthquake in 1841 that only 100 houses and a church were left standing and the capital was reestablished in San José. After San Salvador, the capital of El Salvador, was destroyed by an earthquake in 1854, the capital was moved to Santa Tecla, which then took the name of Nueva San Salvador. Yet, illustrating the principle that people dismiss the risks from a potentially disastrous event if they are obtaining some benefit by doing so, the nation's capital was relocated again at San Salvador in 1859. The city again suffered heavy damage from earthquakes in 1873 and 1907. Special mention shall be made of Mount Pelée on the Caribbean island of Martinique. After two innocuous active events in 1792 and 1851, the volcano erupted violently on May 8, 1902, completely destroying the City of Saint-Pierre and killing 30,000 people.

Regarding the exploitation of minerals and heat associated with geothermal manifestations, we know of a few notable instances, the most famous one being the mining of sulfur deposits on Popocatépetl. Suárez de Peralta reported in 1589 that the Indians obtained this material from the volcano skirts, and it is legendary that soldiers under Diego de Ordaz took from its crater the sulfur needed by Cortés' army to manufacture gunpowder. These deposits were mined until February 19, 1919, when the company working them exploded a dynamite load that was too large. The explosion provoked an earthquake and a volcanic eruption, resulting in the death of 17 workers. In another curious case, the Nicaraguan authorities extended a permit in 1551 to one Juan Alvarez to excavate the volcano Masaya and extract the molten gold that, he thought, was collected in the depth of its crater.

Also, pools of thermal waters were used for their therapeutic properties by the original settlers and Spanish conquerors, alike. For example, the Baños del Peñón ("Baths of the Boulders"), located in the boundaries of the present-day Mexico City airport, were renowned for healing many ailments.

Subsequent Testimonies

During the 19th century, and notwithstanding the problems in the Mesoamerican region, many foreigners came to visit for different reasons, and many of them left reports about the notable volcanic and seismic activity. For example, Henry Ward (1827), the first British ambassador to Mexico, confirmed that Popocatépetl is an active volcano and speculated on the effects of a sudden thawing of its snow cap due to a "violent eruption." He offered as endorsement to his ominous conclusions the report of a similar event witnessed by Alexander von Humboldt in Ecuador at Cotopaxi in 1802. In the course of a trip that Mr. Ward made in 1827 to inspect mines in the central

part of Mexico, he crossed the Pathé River. Around it, he noticed many "hot springs of mineral waters from which dense sulfurous vapors rose." Precisely in this area, the first geothermal power plant of Mesoamerica was installed in 1959.

Although there are many other references to the geothermal phenomena of Mesoamerica published in the 19th century, we will end by mentioning one especially well known, the study on "Les Geysers de Ixtlán" that Paul Waitz presented at the 10th International Geological Congress in 1906. This paper was among those consulted by the first Mexican geothermicists, like Jorge Isita Septién, Luis de Anda, and Héctor Alonso, whose work made possible modern geothermal development in their country.

Conclusions

The distinct manifestations of terrestrial heat—hydrothermalism, volcanic eruptions, earthquakes, and igneous mineral deposits—always have affected the lives of Mesoamerica's inhabitants in definitive ways. At a fundamental level, the existence of geothermal activity in an area can decide whether or not its occupants will live or die. But geothermal manifestations also have less categorical influences. They can affect utilitarian aspects, as when people profit from the increased fertility of volcanic soils, exploit igneous materials, and use hot springs to bathe or heal. On a nonmaterial plane, they can foster the advancement of scientific theories to explain geothermal phenomena, the proposal of philosophical developments related to the Earth's heat in a general way, and the creation of complete plutonic theogonies.

In recent years, specialists of diverse disciplines—but mostly geologists and engineers working with geothermal exploitation, anthropologists, and historians of science and technology—have addressed this subject, and there is a growing bibliography. We hope that the study of the history of relationships between people and geothermal phenomena will continue for a long time.

Plumbing Fiery Liquor for Gold in Masaya

John L. Stephens, while traveling in Nicaragua, visited the volcano Masaya in 1841 and relates these two stories in his book *Incidents of Travel in Central America, Chiapas and Yucatan, Vol. II*. The story of the descent down the crater surely occurred around 1551. Perhaps one of the two Spaniards involved was Alvarez, the man permitted by the Nicaraguan government to explore it.

Stephens wrote, "Among the recorded wonders of the discoveries in America, this mountain was one; and the Spaniards, who in those days never stopped half way in any matter that touched the imagination, called it El Infierno de Masaya, or the Hell of Masaya.

"The historian, in speaking of Nicaragua, says, 'There are burning mountains in this province, the chief of which is Masaya, where the natives at certain times offered up maids, throwing them into it, thinking by their lives to appease the fire, that it might not destroy the country, and they went to it very cheerful.'

"In another place he says, 'There is another Mouth like that of a Well about a Bowshot over [from Masaya's crater], the distance from which to the Fire is about a hundred and fifty Fathoms, always boiling up, and that mass of Fire often rises and gives a great Light, so that it can be seen at a

considerable Distance. It moves from one Side to the other, and sometimes roars so loud that it is dreadful, yet never casts up anything but Smoke and Flame.

"'The Liquor never ceasing at the Bottom, nor its Boiling, imagining the same to be Gold, *F. Blas de Iñesta*, of the Order of *St. Dominick* [*sic*], and two other *Spaniards*, were let down into the first Mouth in two Baskets, with a Bucket made of one Piece of Iron, and a long Chain to draw up some of that fiery Matter, and know whether it was Metal. The Chain ran a hundred and fifty Fathoms, and as soon as it came to the Fire, the Bucket melted, with some Links of the Chain, in a very short Time, and therefore they could not know what was below. They lay there that Night without any Want of Fire or Candles, and came out again in their Baskets sufficiently frighted.'" *Courtesy Dover Publications, Inc.*

Antigua Destroyed
By John L. Stephens, 1841

"Yet this city [Antigua, Guatemala], surrounded by more natural beauty than any location I ever saw, has perhaps undergone more calamities than any city that was ever built.... At the corner of the street was the ruined church of Santo Domingo, a monument of the dreadful earthquakes which had prostrated the old capital, and driven the inhabitants from their home.

"On each side were the ruins of churches, convents, and private residences, large and costly, some lying in masses, some with fronts still standing, richly ornamented with stucco, cracked and yawning, roofless, without doors or windows, and trees growing inside above the walls. Many of the houses have been repaired, the city is repeopled, and presents a strange appearance of ruin and recovery. The inhabitants, like the dwellers over the buried Herculaneum, seemed to entertain no fears of renewed disaster. I rode up to the house of Don Miguel Manrique, which was occupied by his family at the time of the destruction of the city, and, after receiving a kind welcome, in company with Señor Vidaury walked to the plaza.

"The print above [by Frederick Catherwood] will give an idea, which I cannot, of the beauty of this scene. The great volcanoes of Agua and Fuego look down upon it; in the centre is a noble stone fountain, and the buildings which face it, especially the palace of the captain general, displaying on its front the armorial bearings granted by the Emperor Charles the Fifth to the loyal and noble city, and surmounted by the Apostle St. James on horseback, armed, and brandishing a sword; and the majestic but roofless and ruined cathedral, three hundred feet long, one hundred and twenty broad, nearly seventy high, and lighted by fifty windows, show at this day that La Antigua was once one of the finest cities of the New World, deserving the proud name which Alvarado gave it, the city of St. James of Gentlemen.

"This was the second capital of Guatemala, founded in 1542 on account of the destruction of the first by a water volcano. Its history is one of uninterrupted disasters.... 'Many severe shocks of earthquakes were felt at different periods; the one in 1565 seriously damaged many of the principal buildings; those of 1575, 76, and 77 were not less ruinous. On the 27th of December, 1581, the population was again alarmed by the volcano, which began to emit fire; and so great was the quantity of ashes thrown out and spread in the air, that the sun was entirely obscured, and artificial light was necessary in the city at midday.

"'The year 1585 and 6 were dreadful in the extreme. On January 16th of the former, earthquakes were felt, and they continued through that and the following year so frequently, that not an interval of eight days elapsed during the whole period without a shock more or less violent. Fire issued incessantly, for months together, from the mountain, and greatly increased the general consternation. The greatest damage of this series took place on the 23d of December 1586, when the major part of the city again became a heap of ruins, burying under them many of the unfortunate inhabitants; the earth shook with such violence that the tops of the high ridges were torn off, and deep chasms formed in various parts of the level ground.

"'On the 18th of February, 1651, about one o'clock, afternoon, a most extraordinary subterranean noise was heard, and immediately followed by three violent shocks, at very short intervals from each other, which threw down many buildings and damaged others; the tiles from the roofs of the houses were dispersed in all directions, like light straws by a gust of wind; the bells of the churches were rung by the vibrations; masses of rock were detached from the mountains; and even the wild beasts were so terrified, that, losing their natural instinct, they quitted their retreats, and sought shelter from the habitations of men.

"'The year 1717 was memorable; on the night of August 27th the mountain began to emit flames, attended by a continued subterranean rumbling noise. On the night of the 28th the eruption increased to great violence, and very much alarmed the inhabitants. The images of saints were carried in procession, public prayers were put up, day after day; but the terrifying eruption still continued, and was followed by frequent shocks, at intervals, for more than four months. At last, on the night of September 29th, the fate of Guatemala appeared to be decided, and inevitable destruction seemed to be at hand. Great was the ruin among the public edifices; many of the houses were thrown down, and nearly all that remained were dreadfully injured; but the greatest devastation was seen in the churches.

"'The year 1773 was the most melancholy epoch in the annals of this metropolis; it was then destroyed, and, as the capital, rose no more from its ruins... About four o'clock, on the afternoon of July 29, a tremendous vibration was felt, and shortly after began the dreadful convulsion that decided the fate of the unfortunate city... On the 7th September there was another, which threw down most of the buildings that were damaged on the 29th of July; and on the 13th December, one still more violent terminated the work of destruction... A meeting was convoked for the purpose of collecting the sense of the inhabitants on the subject of the removal... It was resolved to make a formal translation of the city of Guatemala to the Valley of Las Vacas. The king gave his assent to this resolution on the 21st of July, 1775... On the 29th of July, 1777, a proclamation was issued in Old Guatemala, commanding the population to remove to the new city within one year, and totally abandon the remains of the old one.'

"Such is the account given by the historian of Guatemala concerning the destruction of this city; besides which, I saw on the spot Padre Antonio Croques, an octogenarian, and the oldest canonigo in Guatemala, who was living in the city during the earthquake which completed its destruction. He was still vigorous in frame and intellect, wrote his name with a free hand in my memorandum book, and had vivid recollections of the splendor of the city in his boyhood, when, as he said, carriages rolled through it as in the streets of Madrid. On the fatal day he was in the Church of San Francisco with two padres, one of whom, at the moment of the shock, took him by the hand and hurried him into the patio; the other was buried under the ruins of the church. He remembered that the tiles flew

from the roofs of the houses in every direction; the clouds of dust were suffocating, and the people ran to the fountains to quench their thirst. The fountains were broken, and one man snatched off his hat to dip for water. The archbishop slept that night in his carriage in the plaza. He described to me the ruins of individual buildings, the dead who were dug from under them, and the confusion and terror of the inhabitants; and though his recollections were only those of a boy, he had material enough for hours of conversation.

"In company with the cura we visited the interior of the Cathedral. The gigantic walls were standing, but roofless; the interior was occupied as a burying-ground, and the graves were shaded by a forest of dahlias and trees seventy or eighty feet high, rising above the walls. The grand altar stood under a cupola supported by sixteen columns faced with tortoise shell, and adorned with bronze medallions of exquisite workmanship. On the cornice were once placed statues of the Virgin and the twelve apostles in ivory; but all these are gone; and more interesting than the recollections of its ancient splendor or its mournful ruins was the empty vault where once reposed the ashes of Alvarado the Conqueror."

From Incidents of Travel in Central America, Chiapas and Yucatan, Vol. I., *courtesy Dover Publications, Inc.*

Mining Sulphur from Popocatépetl

"The Spaniards, five in number, climbed to the very edge of the crater, which presented an irregular ellipse at its mouth, more than a league in circumference. Its depth might be from eight hundred to a thousand feet. A lurid flame burned gloomily at the bottom, sending up a sulphurous steam, which, cooling as it rose, was precipitated on the sides of the cavity. The party cast lots, and it fell on Montaño himself [their leader] to descend in a basket into this hideous abyss, into which he was lowered by his companions to the depth of four hundred feet! This was repeated several times, till the adventurous cavalier had collected a sufficient quantity of sulphur for the wants of the army. This doughty enterprise excited general admiration at the time. Cortés concludes his report of it [in the early 1500s] to the emperor with the judicious reflection that it would be less inconvenient, on the whole, to import their powder from Spain."

From History of the Conquest of Mexico*, by William Prescott, 1873*

Selected References

Burgassi, P.D., R. Cataldi, J.L. Hernández-Galán, M. Moggi, R. Rubinovich, and J.J. Saldaña (1992). *Primera contribución al conocimiento historiográfico de la energía geotérmica en el Area Mediterránea y en la América Latina.* Pisa. (Prepared for and presented at the Symposium on the History of Geothermal Energy, Mexico City, 1992. Limited publication. For further information, contact the first three authors at the addresses in this volume).

Calderón de la Barca, F. (1843) *Life in Mexico.* University of California Press, Berkeley, California.

Cárdenas, J. (1591) Primera parte de los problemas y secretos maravillosos de las Indias. In *Historia de la ciencia en México Siglo XVI.* Reprint 1983, E. Trebulse. Fondo de Cultura Económica, México, D.F.

Castañeda de Nájera, P. (1560) Relato de la expedición de Coronado. In *La última jornada de Melchor Díaz.* Reprint 1973, R L. Ives. *Revista CALAFIA,* yr. 2, no. 2, 18-21.

Díaz del Castillo, B. (1568) *Historia verdadera de la Conquista de la Nueva España.* Fernández Editores, S.A., México, D.F.

Fernández de Oviedo, G. (1526) *Sumario de la natural historia de las Indias.* Fondo de Cultura Económica, México, D.F.

Fink, J. (1993) Down under the volcano. *Nature,* 366, 108.

Grayson, D.K. and P.D. Sheets (1979). Volcanic disasters and the archeological record. In *Volcanic activity and human ecology.* Academic Press, Inc.

Hurtado de Mendoza, L. y G. Alvarado (1988). Datos arqueológicos y vulcanológicos de la región del Volcán Miravalles, Costa Rica. *Vínculos,* 14, 77-89.

Longyear III, J.M. (1952). *Copán ceramics.* Carnegie Institution of Washington, Washington, D.C.

López de Gómara, F. (1552). *Hispania victrix, Primera y segunda parte de la historia general de las Indias.* Ediciones Orbis, S.A., Barcelona.

Muñoz Carmago, Diego (1540). *Historia de Tlaxcala.* Reprint 1963. In *Visión de los vencidos,* M. León Portillo y A. M. Garibay, eds. Fondo de Cultura Económica, México, D.F.

Prescott, William H. (1873) *History of the conquest of Mexico, vol 2.* David McKay, Philadelphia, Pennsylvania.

Ryder, P. (1983). Guayabo de Bagaces. *Vínculos,* 14, nos. 1-2, 121, 125.

Sahagún, B. de (1534). Historia general de las cosas de Nueva España. Reprint 1963. In *Visión de los vencidos,* M. León Portillo y A.M. Garibay, eds. Fondo de Cultura Económica, México, D.F.

Sharer, R.J. (1979). *Sucesos terminales en el sureste de Guatemala.*

Sheets, P.D. (1979) Volcanic eruption effects. In *Volcanic activity and human ecology.* Academic Press, Inc.

Sheets, P.D. (1984) Proyecto prehistórico Arenal during 1984: Summary and conclusions. *Vínculos,* 10, nos. 1-2, 207-223.

Stephens, J.L. (1841) *Incidents of travel in Central America, Chiapas and Yucatan, vols. 1-2.* Dover Publications, New York.

Stone, D. (1941a) *Precolumbian man finds Central America: The archeological bridge.* Peabody Museum Press, Boston.

Stone, D. (1941b). Archeology of the north coast of Honduras. *Peabody Museum Transactions,* 9, no. 1, 25-29.

Suárez de Peralta, J. (1589). *Tratado del descubrimiento de las Indias.* Consejo Nacional para la Cultura y las Artes, México, D.F.

Tedlock, D. (1985). *Popol Vuh, The definitive edition of the Mayan book of the dawn of life and the glories of gods and kings.* Simon & Schuster, Inc., New York.

3.3 Heat over Time: Geothermal Stories from Mexico (Chapter 33)
By S.F. Hodgson

Abstract:

Mexican geothermal stories, ancient and modern, written and oral, record the history of geothermal Mexico. The stories in this chapter span hundreds of years. Some are from a 1541 Spanish manuscript about the just-conquered P'urhépecha, an indigenous people in central Mexico. The rest are oral transcriptions made in 1993 and 1994 at Mexican geothermal sites.

The stories offer historical commentary and drama shaped by magic realism. They include P'urhépecha political and religious ceremonies, Maya beliefs, Spanish conquistadors, the Mexican War of Independence, and country life after the Conquest.

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The Beginning

There are many geothermal stories in Mexico—remembered, forgotten, oral, and written. Here are a few. Some have characters and plots; others do not. All show how geothermal settings influence lives, the story of heat over time.

The P'urhépecha stories are first, as accounts from this indigenous Mexican people started my search. The P'urhépecha still live in the heart of Mexico, in the modern State of Michoacán. Today, their lands are bordered on the east by the State of Mexico and Mexico City, once the home of the Aztecs, an ancient enemy. Much of P'urhépecha culture was destroyed with the Spanish Conquest, which came to Michoacán in 1521.

Soon afterwards, from 1539 to 1541, a Franciscan friar, probably Jerónimo de Alcalá, interviewed the P'urhépecha and compiled the only known survey from the time of their government, customs, and traditions. He called it the *Relación de las Ceremonias y Ritos y Población y Gobierno de los Indios, de la Provincia de Michoacán,* or *The Story of the Ceremonies and Rites and People and Government of the Indians, of the Province of Michoacán.*

In the *Relación*, the hot springs and volcanoes of Michoacán are woven into religious ceremonies and stories, as are many sites and cities existing today, including the volcanic hills of Zinapécuaro and the hot springs of Araró. These towns are mentioned in the following story about the P'urhépecha feast of *Sicuíndiro*, which means "the skinning" and honors the goddess of rain, who made rain clouds in Zinapécuaro and kept them as vapor in the sacred hot springs of Araró. The portion that follows retains its original cadence from the oral tradition when read aloud.

***Sicuíndiro* (The Skinning)**
Narrative of the P'urhépecha
Relación, *translated by S. Hodgson*
(Probably) compiled by Friar Jerónimo de Alcalá
Michoacán, Mexico, 1539-1541

"Five days before this feast,
the priests arrived from the towns mentioned,
with their gods, and they came to the feast,
and dancers called *cesquárecha* entered the houses of the priests
and two other priests called *hauripitzípecha*,
and they fasted until the day of the feast,
and the day before the feast,
the priests marked the chests of two slaves or criminals that
they had to sacrifice the day of the feast,
and they sacrificed the slaves mentioned,
and in taking the hearts, they performed their ceremonies with them,
and while they were still warm,
they carried them to the hot springs of the town of Araró from the town of Zinapécuaro,
and they threw them in a small hot spring,
and they covered them with wooden tablets,
and they threw blood in all the other hot springs that are in the town mentioned,
that were dedicated to other gods that were there,
and those hot springs gave off vapor,
and they said that from there the clouds left to rain,
and this goddess called Cuerauáperi was in charge of them,
and that she sent them from the east, where she was,
and for this reason they threw that blood in the springs."

Araró, which means "the perforation site," received its name from the feast when great warriors received lip rings, nose rings, and earrings. Blood let during the insertion was thrown in the hot springs (Corona Nuñez, 1977). Two great P'urhépecha warriors standing behind the Franciscan friar in the drawing at the front of the chapter have rings in their lower lips, most likely inserted at this ceremony.

I visited Zinapécuaro and Araró, searching for geothermal stories.

At Zinapécuaro

In Zinapécuaro, on the outskirts of town, a sign advertises hot springs at a resort of therapeutic and recreational renown, *La Reina Atzimba*—the Queen Atzimba.

Stopping nearby, I asked a family about geothermal stories. They directed me to María Guadalupe Avalos, a life-long resident of the town. Señorita Avalos spoke about Queen Atzimba, calling her Princess Atzimba, and this is what she said.

Princess Atzimba
Brief narrative of María Guadalupe Avalos
Zinapécuaro, Michoacán, Mexico, May 1994

"Princess Atzimba was the sister of a P'urhépecha king named Zuangua. His palace is on a hill called *Las Clavellinas* that is by the resort of *La Reina Atzimba*, on the edge of town."

This was the hot spring resort I had passed on the way. Although archaeological ruins found here predate the Conquest, the main temple of Cuerauáperi was elsewhere. The *Relación* states:

> "Cuerauáperi had her priests in the town of Araró and other towns,
> and her main idol in a temple
> that is in the town of Zinapécuaro, on top of a hill,
> where today it is demolished."

Lopez Lara writes that Cuerauáperi's temple was built and torn down on the hill today at the center of modern Zinapécuaro, the site where the Spaniards built the city's main church in 1570. He thinks the church was built on the ruins of her temple, following the Spanish dictum, "temple over temple."

I thought of other Mexican cities with their main churches on flat, central plazas, and Zinapécuaro has a lot of flat terrain. Yet it is true that the main church stands on a singular rise about two blocks higher than the terrain around it. Why weren't the flatter areas used, unless the main temple for Cuerauáperi had stood on that hill?

To approach the church, you walk for about two blocks up a straight narrow street ending in two tiers of steps. The walkway rises up to the church in a carefully graded way, paved with stones perhaps especially well placed. Her old temple entranceway?

On to Araró

Leaving Zinapécuaro, I drove about six kilometers north to Araró, to the field of hot springs where Cuerauáperi kept the clouds. In town I met Carlos Ferrer, a young man about 15 years old, who led the way through modern Araró out to the ancient field of hot springs described in the *Relación.* As we drew near, we passed thriving plots of corn, and Carlos explained that thermal vapors helped the corn to grow, that sometimes hot springs were used for cooking the ears of corn.

Finally we came to the ancient field of hot springs and the two modern resorts at the edge, Balneario Los Hervideros and Balneario Huingo. We parked and entered the large flat expanse a few square kilometers in size, covered with brown meadow grass and about 17 hot springs, by Carlos' estimate. He said that once a geyser, called *El Géiser*, had shot straight up and an apparition had appeared here, the "Señor de Araró." He pointed to an especially large hot spring resembling a collapsed cave, named *La Cueva del Diablo*, or "The Devil's Cave."

In the field I saw several small sites for collecting salt. At each, a wooden funnel about 1½ meter wide and high was erected over a few covered troughs. First the funnels were filled with soil from the field. Then water was poured into them, leaching out the salts and dripping into the troughs. Here the water evaporated into a salty residue. Carlos said that salt collection is an old practice, that his grandfather had done it.

Fig. 13. Portion of an illustration from Chapter XIX of the "Relacion." The comet is one of two that warned the Tarascan Indians of the imminent Spanish Conquest. The mountain on the right, sparsely covered with pine trees, closely resembles the topography and vegetation of Los Azufres Geothermal Field. The figures are of gods who appeared in a dream and their divine natures are indicated by the exaggerated features and teeth.

Much of the field looked natural and untouched, perhaps not too different from the days of Cuerauáperi. Then I noticed highway construction crews working at the far edge, building the new superhighway across the State of Michoacán to connect Mexico City with Guadalajara. The superhighway crosses Araró's field of hot springs, and special efforts were made to save hot springs in its path.

We went to take a closer look. The superhighway rises like a bridge across the field. Between the columns that support its spans are small passageways three to four meters wide. Some passageways have holes in their concrete floors about a meter wide. Here preserved hot springs bubble and steam away, still storing the clouds.

From Araró to Los Azufres

The P'urhépecha believed in omens and dreams, which warned them of the Conquest at least four years before the Spaniards arrived. I believe the pine forests, volcanoes, and thermal areas of Los Azufres Geothermal Field in Michoacán are included in a dream recounted in the *Relación.* Drawings and text from the *Relación* support this, but not conclusively.

In the dream, a P'urhépecha woman is flown on the back of an eagle over steep mountain slopes covered by pine trees. The topography and vegetation of the slopes, illustrated in Plate XLII from the *Relación*, are identical—albeit in rough-sketch format—to the topography and vegetation at Los Azufres Geothermal Field today.

On the journey, they fly over a mountain with a hot spring whose description matches that of a famous hot spring, *Laguna de Los Azufres* ("Lagoon of Sulfurs"), found today on the southern edge of Los Azufres Geothermal Field. The *Relación* describes the hot spring as surrounded by sulfur-bearing rock. The lagoon is indeed surrounded by such rock, which was mined for its sulfur in the 1800s. Here is the dream.

"Of the Omens and Dreams This People Had before the Spanish Came to This Province"

Relación, *Chapter XIX, translated by S. Hodgson*
Narrative of the P'urhépecha
Michoacán, Mexico, 1539-1541

"The goddess Cuerauáperi, mother of all earthly gods,
came and took that woman from her own house,
guided her awhile toward the road from Mexico,
and turned her toward the road to Araró,
And that woman went by the road,
and on the road she met an eagle that was white,
and it had a large cape in front,
and the eagle began to whistle, and to arch its feathers,
and with some large eyes that they said to be the god Curicaueri, and the eagle greeted her, and told her that she was welcomed, and she also greeted him,
and told him: 'Sir, you come just in time.'
The eagle told her, 'Climb up here, on top of my wings,
and don't be afraid of falling.'
And just as the woman climbed up,
the eagle rose up with her, and began to whistle,
and carried her to a mountain, where there is a hot spring,
and sulfur in the rock,
and carried her by that mountain flying with her,
and now dawn was breaking,
when he carried her to the foot of a very high mountain,
that is near there, called Xanoato-hucatzio,
and carried her high,
and that woman saw
that all the gods of the province were seated."

Solemnly, the gods warn the woman that invaders are coming, that "everything will be gone, other men will be throughout the land." They say she must warn everyone, including King Zuangua, that the fates of the P'urhépecha people and the gods themselves depend on him.

Though warnings were issued, King Zuangua ignored them and the Conquest came. It began in 1519 to the southeast, where many indigenous peoples were attacked, including the Aztecs. The Aztecs appealed twice for help from the P'urhépecha and were refused both times. First they petitioned aging King Zuangua, who would die of smallpox in 1520. They next asked his heir, but to no avail. By 1521, the Aztecs were conquered and the Spaniards had moved into P'urhépecha lands, where the onslaught continued (Bravo Ugarte, 1963).

Now at Los Azufres

Today, 473 years later, just on the northern edge of Los Azufres Geothermal Field, Doña Celia Escalante Arreola runs a small hot spring resort on lands where her family has lived at least as far back as her great-grandparents. On her front porch, she told me a very short story of an Aztec queen, *Xóchitl*, which means "flower." The Los Azufres area was a boundary between P'urhépecha and Aztec lands, and her account reflects the cultural interface. This is what she said.

Queen Xóchitl

Brief narrative of Celia Escalante Arreola
Michoacán, Mexico, May 1994

"When I was a child, Queen Xóchitl would bathe here in the thermal waters. She did this because the waters were beautiful and kept you young."

As she spoke, Doña Celia nodded to the southeast, indicating the location of the hot spring—the same direction as the nearby famous Lagoon of Sulfurs, although she didn't mention it by name. She said that the Virgin of Guadalupe has appeared there as well.

The next two stories feature Los Azufres Geothermal Field and the Lagoon of Sulfurs at its southern border. The stories are by Arturo González Salazar, a geologist who has worked extensively in Mexican geothermal fields. Comments by Celina Silva and others are included.

The History of Los Azufres

Narrative of Arturo González Salazar
Morelia, Michoacán, Mexico, November 1993, May 1994

Additional narrative by Celina Silva
Agua Fría, Michoacán, Mexico, May 1994

"In 1968, I arrived in the high pine forests of eastern Michoacán," said Arturo González Salazar. "I explored the geology of a place now called Los Azufres Geothermal Field in the Parque Nacional de Los Azufres [Los Azufres National Park]. The Comisión Federal de Electricidad [CFE] sponsored my work and I lived by the famed Lagoon of Sulfurs, today on the field's southern edge. This hot spring area, known through centuries

for steamy vapors and curative waters, is just south of the CFE's main field camp and a volcano called Las Humaredas, so named by people mistaking its vapors for smoke.

"When I came to Los Azufres, almost no one was there. One day I climbed the slopes of Las Humaredas, and near the top in a flat grassy area, I found rock patterns laid out on the ground and some rocks piled into a triangle.

"Small funerary rock piles and triangular rock mounds were by the Lagoon of Sulfurs as well, and I asked about them. The country people said the rocks were from the past, part of P'urhépecha religious ceremonies when a young girl entered puberty.

"From the time of the P'urhépecha, there are stories of women seeking fertility in the waters of Los Azufres, and of people bathing to alleviate rheumatism and arthritis. When I came, I saw many using the waters for cures. Poor rural people arrived on burros, bringing along their own food and blankets.

"For the P'urhépecha, the lagoon was a sanctuary and a center of religious life. Priests held ceremonies in the early morning when vapors from the hot waters were intense. We can imagine them colorfully dressed, standing in the hot coiling vapors, worshiping the sun.

"The lagoon served other purposes. P'urhépecha society was very hierarchical and the country people told of large, periodical P'urhépecha migrations to the lagoon, where leaders would undertake the formal rites matched to their political status, mixing religion and power. Ceremonies were held at nearby Cerro Las Humaredas as well.

"All this ended with the Spanish. After Cortés began the Conquest of Mexico in 1519, the Spaniards moved quickly to alter native religious expression. At first this did not stop people from worshiping secretly in small groups, continuing to speak with their gods, but then it did. One day at Los Azufres, I found an ancient Spanish coin from that time.

"The end for Mexico of almost 300 years of Spanish rule began on September 15, 1810, in the State of Guanajuato with Miguel Hidalgo's famous cry, 'El Grito de Dolores.' His proclamation is considered the Declaration of Independence for Mexico. The revolution spread south into Michoacán, which quickly became a center of the conspiracy and a home for revolutionary leaders.

"Because the revolutionaries had no gunpowder, they made their own. They mined sulfur, the main ingredient, at Los Azufres from the rock surrounding the Lagoon of Sulfurs, perhaps increasing the size of the hot spring in the process. Walking around the lagoon today, you pass several old mine shafts filled with water. The revolutionaries drained the water through a channel cut into solid rock.

"Once the sulfur-rich rock was mined, it was brought to a nearby gunpowder factory built where the CFE has placed its main field camp at Los Azufres. The factory itself was over a stream, the Arroyo de Agua Fría, a source of water in case of attack. At the base of a fragment of wall still standing, a beautiful stone archway marks where the creek flowed through it, passing into the building.

"The rocks with sulfur were pulverized at the factory by large grinding wheels. Today one of the wheels is displayed on a rise overlooking the field camp. The gunpowder factory was among the first in Mexico and the source of the first gunpowder used in the revolution. When the war was over and no more gunpowder was needed, the factory was abandoned."

Celina Silva told Arturo González Salazar and me that the sulfur miners used large pots, called *cazos*, to process the sulfur into large pieces called *marquetas.* Some miners were injured or killed by fumes of hydrogen sulfide. The factory had a special area for storing explosives.

Celina Silva grew up at Los Azufres, and both she and Doña Celia said it was once part of the Hacienda Agua Fría and the home of Melchor Ocampo, a prominent Mexican political figure in the mid-1800s. Celina said that the father of the revolutionary priest, Miguel Hidalgo, had lived at Los Azufres. I asked the CFE if old land records could confirm this, but unfortunately nothing in the files could. I was disappointed, for this could be the way revolutionaries had learned of sulfur at the Laguna de Los Azufres.

Arturo González Salazar continued, "When I came to Los Azufres, just a few sections of factory wall remained. A man living nearby told me about the ghosts, saying that in the vapors of Los Azufres he had seen the ghosts dressed in costumes from the days of the Conquest and from the time of the gunpowder factory. He and others never went out at night for fear of meeting them.

"I was sent to Los Azufres because Luis de Anda, in the newly formed CFE, had placed the area on a list he made in the 1940s of geothermal sites to be developed for electrical generation. Thus, I saw the famous thermal features and forested hillsides almost untouched by mankind.

"Today Los Azufres is a national park and beautiful, but at the same time some things have passed away and changes have come. Some are from geothermal development, of course, though Los Azufres Field is a good geothermal project and great care has been taken.

"Even so, for a long time I didn't go back; I didn't want to return. I feared the ghosts in the vapors, the sight of Los Azufres as it used to be."

The next story, also by Arturo González Salazar, is a geothermal legend about a hot spring a few kilometers away from the Lagoon of Sulfurs, called *El Pozo del Currutaco*.

El Pozo del Currutaco

"A *currutaco* is an old-fashioned pejorative in Spanish meaning a man with exaggerated elegance, a dandy. A hot spring in Los Azufres Geothermal Field is called *El Pozo del Currutaco*, and this is how it got its name.

"At the turn of the century, a *currutaco* came to a small community not so far from the hot spring where he fell in love with a woman who had another suitor.

"The *currutaco* was very elegant and perhaps even handsome. The woman loved him for this, and forsook the first suitor who was humble and poor.

"One day, an outing was arranged into the countryside at the hot spring. The party included the *currutaco*, the woman, and her humble suitor.

"At a propitious moment, the humble suitor pushed the *currutaco* into the hot spring. The water was so hot, the *currutaco* couldn't get out and he died.

"Thus through crime, the humble suitor changed his fate and came to marry the woman he loved. Ever since the hot spring has been called *El Pozo del Currutaco*.

"Today the scalding waters are still famous. People come from miles around. Kneeling by the hot spring, wary of splattering bubbles, they reach inside to dig out clay for beauty masks, poetic justice for the handsome *currutaco*."

Chiapas

This story by Arturo González Salazar is from the State of Chiapas. Though modern, it may be the oldest of all, an evocative paradox of nature, mankind, and geothermal resources, and a volcano named Chichonal.

My Days at Chichonal

"About 20 years ago in the Mexican State of Chiapas, a governor phoned the Comisión Federal de Electricidad [CFE]. He said he had flown over a mountain on fire, smoke billowing from its sides. The governor asked the CFE to come to Chiapas and explore the mountain, a volcano called Chichonal, for he feared something serious could happen.

"The CFE sent a geochemist, Rafael Molina Berbeyer (now deceased), a geologist (myself), and a technician, Blas González Mendez. After a long journey, we finally arrived in the town of Pichucalco in Chiapas. From there, we drove with great difficulty to a little town called Volcanes, a site very isolated in the heart of tropical jungle. It was a dangerous trip and we crossed several wide rivers by jeep.

"When we arrived in this small farming commune (whose members were Mayan, of a tribe called the Zoque), the town authorities let us stay in the school. We spread out our belongings and that evening talked to people who returned from the fields. We explained why we had come and asked them to take us to the volcano Chichonal, now not so far away. We could see the 'smoking fumaroles' from the town.

"To our great surprise, nobody would go. This was very unusual for in general the people we met were helpful. Finally, we convinced a small group to guide us up the slopes of the volcano. The leader was a man named Cansino, who agreed on condition that we would walk ahead of him.

"The next day, we penetrated an untouched jungle of rich, tropical vegetation without roads or trails. We went first and our hesitant guides stayed a distance behind, nervous and fearful. From time to time, passing carefully through dense foliage and stands of huge leaves, Cansino and I spoke. Gradually I realized that he feared visiting the volcano because he had heard its loud noises. He had watched birds flying near fumaroles fall dead from the sky and feared he, too, would die.

"I found it no mystery what had killed the innocent birds—the hydrogen sulfide gases breathed in from the vapors.

"Hours later we came to the fumaroles but stayed briefly, for the hydrogen sulfide fumes were intense. Then we returned to Volcanes. Here, Cansino convinced others that the situation was not perilous, that they should help establish our camp at the top of the volcano. With great organization they did so, bringing us food and water each day.

"With time more people began to help, while we explored one of the most remarkable geothermal zones I have ever known. The temperatures were very high, there were immense areas of fumaroles, and more enchanting, perhaps because it was unvisited by any human being, the zone was a verdant and natural sanctuary for animals I had known in books but had never seen.

"On the days I stayed there I saw many deer, tapirs, peccaries, snakes of many kinds, and birds of all colors and sizes. Many times I felt like Christopher Columbus in the New World, finding a paradise full of thriving plants and animals. It was something extraordinary.

"In the nighttime, I meditated. I knew breaking into this sanctuary would have mortal consequences, because teaching the people to enter here without fear would increase man's predation. I have always regretted this, but it was our job to explore the volcano.

"Nonetheless, I listened with hope to Cansino, their leader, who said that hunters would not be permitted to kill in this place, although the taboo was gone. For seeing us move calmly through the vapors, our guides had lost their fear.

"After 45 days we were done. Working in heat over 40° C and in constant rains and cyclones from the Caribbean Sea, we had sampled vapor, measured the temperature of land, and mapped the area. The hydrogen sulfide was so concentrated that we often had headaches, but clearly great geothermal promise existed.

"In my report, I wrote that we had felt tremors from five to six earthquakes each day, that perhaps the volcano of Chichonal was awakening. Thus with several kilos less of weight, without our boots, and with dirty clothing, our mission was ended and we returned home.

"Years later, in 1982, the volcano Chichonal erupted, spewing volcanic ash that changed the climate of the world and destroyed nearby areas, including the sanctuary with the flora and fauna I had so admired. With time, they have told me that almost all my friends and guides of Chichonal died in the catastrophe, which in the end brought destruction, death, and sorrow to the Zoque tribe.

"As a final note, perhaps it is worthwhile here to remember the geologist Salvador Soto Pineda, who died in one of the eruptions while trying to save a community. It was when the volcano was in its full eruptive cycle and some people living in a little town nearby did not wish to evacuate their homes. Salvador Soto Pineda went to convince them to leave, for the risk of death was clear. He and others arrived by helicopter in a humanitarian effort. Once in the town, all were surprised by an eruption and buried forever under tons of volcanic ash. For this I consider Salvador Soto Pineda a hero of volcanology."

Geothermal Stories

Thus geothermal forces destroy lives, and geothermal sites enhance them. Just where devastation reigns from earthquakes, eruptions, lava, hot water, fumes, and fire, there the gods and mortals commune, ailments are alleviated, beauty perfected, crop growth quickened, food cooked, sulfur and salt mined, resorts visited, and energy made. Geothermal stories record it all.

But our affinity to geothermal forces goes deeper. A quote from Benito Bravo helps illustrate the connection. Benito lives in the P'urhépecha town of Angahuán, which is near Parícutin, the volcano that rose in 1943 in the middle of a cornfield in Southwestern Michoacán.

Angahuán remained untouched by lava flows covering nearby areas. I asked Benito what people in Angahuán think about Parícutin, which has so influenced their lives and he said, "It is important because we saw it when it was born and when it died."

Birth and death. Like us, geothermal features begin and end, moving through cycles of their own. We draw towards them, lured by change, beauty, and an unusual cast of the familiar—water, rocks,

and heat. We search them for answers to mysteries in our own lives, like birth and death. We have done this through time, and geothermal stories are the archives of our quest.

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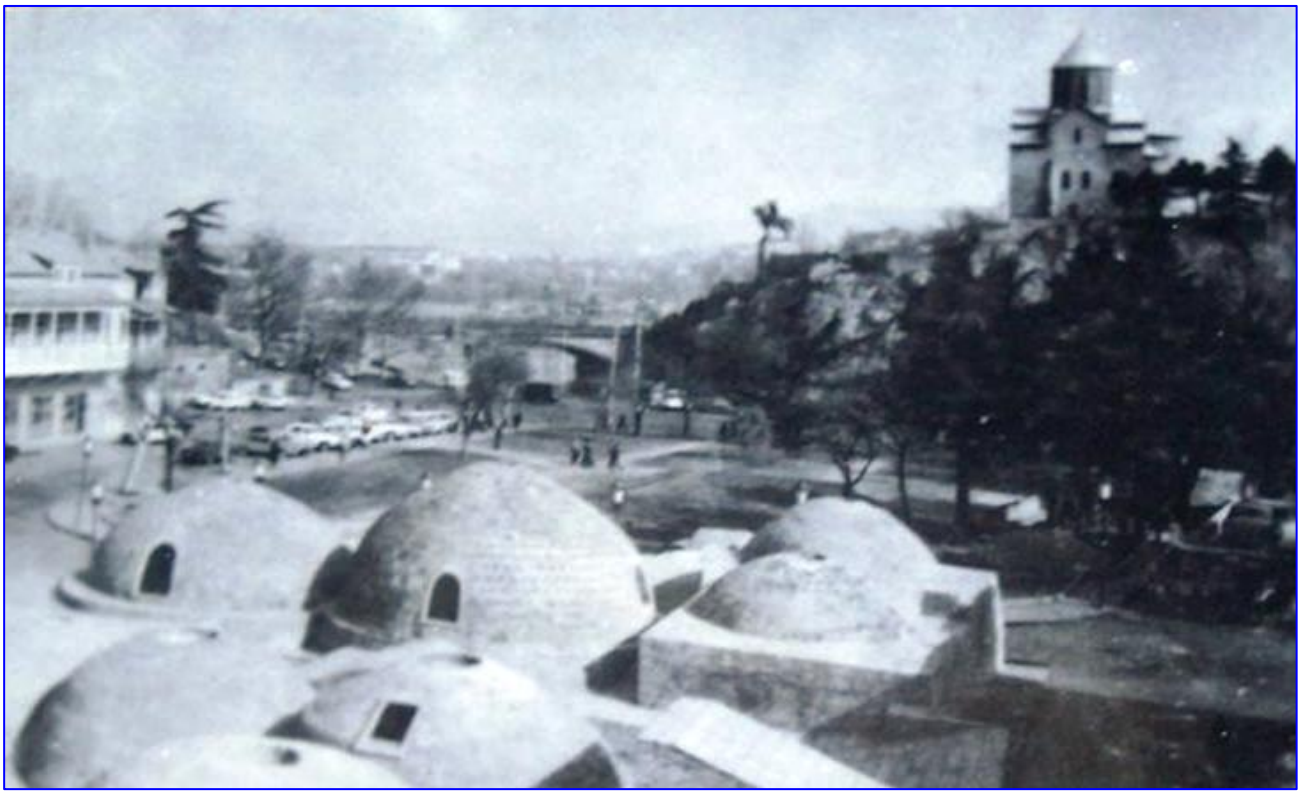

Fig. 14. These ancient temazcals are in Tbilisi, Georgia, built under the Ottoman reign, which began in 1453. The Ottoman Turks had used such baths for centuries in ways similar to the Aztecs.

Selected References

Alcalá, Fray Jerónimo de (most probably) (1541). *Relación de las ceremonias y ritos y población y gobierno de los Indios, de la provincia de Michoacán.* Reprint 1977. Reproduction of the Ms. c. IV. 5. de El Escorial, Spain. Balsal Editores, S.A., Morelia, Michoacán.

Bravo Ugarte, José (1963). *Historia sucinta de Michoacán, Tomo II, Provincia Mayor e Intendencia.* Ed. Jus, S.A. Mexico.

Corona Nuñez, José (1977). Preliminary study. In *Relación de las ceremonias y ritos y población y gobierno de los Indios, de la provincia de Michoacán.* Balsal Editores, S.A., Morelia, Michoacán.

Lopez Lara, Ramón (1984). *Zinapécuaro, Tres épocas de una parroquia.* Tercera Edition. Editado por Fimax Publicistas, Morelia, Michoacán.

Refugio Cabrera V., M., y Benjamín Pérez González (1991). *El estado P'urhépecha y sus fronteras en el siglo XVI.* Carrasquilla Editores, S.A. de C.V., Morelia, Michoacán.

4. EL POSIBLE ORIGEN DE LA PALABRA NAHUATL, *TEMAZCALLI* *(POSSIBLE ORIGIN OF THE NAHUATL WORD,* TEMAZCALLI*)*

Muchas personas han escrito que la palabra *temazcal* proviene de *temazcallí*, que en náhuatl significa: *tema*, "vapor" y *callí*, "casa." No sé si alguien haya considerado que esta palabra náhautl tenga sus propias raíces en dos palabras turcas (una lengua muy antigua), que conforman una palabra todavía usada en Anatolia para un baño muy similar a un temazcal.

Las palabras turcas son: *temiz*, "limpia", y *kal*, una forma imperativa de "quedar", lo que significaría: "quedar limpio". También las costumbres turcas sobre el uso del temazcal son muy parecidas a la de los aztecas. Claro que muchos estudios sobre esto son necesarios, pero es posible que no solamente la idea del temazcal, sino su propia denominación llegaran juntas a México por una ruta desconocida.